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FINAL REPORT

CHARACTERIZING SOLDIER RESPONSES TO IRRITANT GASES

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between the APTS battery and the ASVAB, an instrument known to be predictive of military job performance, and 2) collection and analysis of alcohol dose equivalency data under tightly controlled experimental conditions. Based on task outcomes, regression equations were created to 1) translate reductions in APTS performance due to a treatment such as a mixed gas, into ASVAB equivalent performances, and 2) translate reductions in performance due to a treatment such as an irritant gas into units of percent blood alcohol. *Keywords Previous Page*



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U.S. DEPARTMENT OF DEFENSE

**SMALL BUSINESS INNOVATION RESEARCH PROGRAM  
PHASE 1 — FY 1989  
PROJECT SUMMARY**

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Proposal Title

Characterizing Soldier Responses to Irritant Gases

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Technical Abstract (Limit your abstract to 200 words with no classified or proprietary information/data.)

The purpose of this project was to develop a quantitative definition of soldier performance degradation due to exposure to irritant gases by two linking approaches: Surrogate Measures and Dose Equivalence. Surrogate measures are related to, or predictive of, a construct of interest but are not direct measures. Dose equivalence refers to an experimental method where performance deficits produced with a controlled (and relatively benign) indexing agent, in this case alcohol, are first calibrated against that agent. Then decrements in performance in the presence of irritant gases can be calibrated in terms of their dose equivalence relative to the effects of alcohol. To quantify the human mental acuity functions which are related to military jobs, a portable microcomputer menu of tests, the Automated Performance Test System (APTS), was employed. Two primary tasks were performed: 1) description of the relation between the APTS battery and the ASVAB, an instrument known to be predictive of military job performance, and 2) collection and analysis of alcohol dose equivalency data under tightly controlled experimental conditions. Based on task outcomes, regression equations were created to 1) translate reductions in APTS performance due to a treatment such as a mixed gas, into ASVAB equivalent performances, and 2) translate reductions in performance due to a treatment such as an irritant gas into units of percent blood alcohol.

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Anticipated Benefits/Potential Commercial Applications of the Research or Development

Studies of toxic waste, side-effects of drugs, industrial exposure of potentially hazardous materials, alcohol, dietary supplements, and other exposures to chemical substances require a performance test battery in order to detect, quantify, and calibrate the effects of these agents. Other applications include thermal extremes, motion, noise, sensory deprivation, or overload, as well as other conditions or processes such as aging, dementia, sleep deprivation or emotional strain.

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List a maximum of 8 Key Words that describe the Project.

Irritant Gas — Performance      Performance Testing  
Behavioral Toxicology      Environmental Stress  
Computerized Test Battery

Test Optimization  
Alcohol and Performance

## PROJECT OBJECTIVES

Soldiers in combat are exposed to irritant gases, toxic chemicals and other contaminants which include emissions from guns and rockets (NH<sub>3</sub>; NO<sub>x</sub>, HCl), motorized vehicles (CO, formaldehyde, the hydrazines), fire (CO, CO<sub>2</sub>), fire extinguishers (halon), and various chemical warfare agents (Bloom et al., 1986). In a report of submarine air quality (National Research Council, 1988) 25 pages are devoted to listing substances (gases and particulates) which can have untoward effects on humans. Future plans for Army vehicles such as tanks and helicopters are likely to make them more like the closed systems of the submarine where various concentrations of agents can be expected to impact on human efficiency as well as safety and health.

A workshop (Callahan, 1987) was conducted at the U.S. Naval Submarine Medical Center to evaluate the effects of combined fire products on physiological and psychological performance. It was the consensus of that meeting that we know more about the effects of these irritant gases on animal physiology than we do about their effects on human behavior. Reasons for this lack of knowledge are that human studies are difficult to conduct. Most of our knowledge about the effects of many agents is from chronic stimulations in animal models (usually rodents and guinea pigs). For these studies, usually a live/die (L/D) ratio of 50% is employed to produce transfer functions from which safety standards are devised. However, the information from such studies when new variables are added (e.g., exercise) can make a greater difference from one gas to another (e.g., CO vs HCl - Alarie, 1987) and extrapolation from one animal with one gas to another animal with multiple gases can only be made in general terms. Indeed, and more important, extrapolation of these animal data to acute, sublethal dosages on the human central nervous system must be made with extreme caution (Adler, 1989a; Moses, 1989).

From the standpoint of medical management of humans exposed to environmental agents and stresses, irritant gases may only be tip of the iceberg. The effects of toxic substances of all varieties, either directly (through disruption of synaptic transmission) or indirectly (through irritation and distraction) can impact productivity, attendance, accident rate, learning, etc., in the military and the private sector (Adler, 1989b; Burgess, 1974; Steele, 1986; Winters, 1989; Wise, 1980). Relatedly, one might propose similar issues associated with drugs in the workplace and overall fitness for duty from any cause (e.g., fatigue, sustained performance, irritant gases).

While it may appear that the most straightforward way to assess the effect of environmental stressors on humans is to measure operational performance, when such measures are employed they are generally insensitive to all but the most powerful stressor effects. The lack of quantitative information on individual and team performance has hindered the development of battlefield models, particularly those which must incorporate the effects of stressors such as irritant gases (Kennedy, 1987). In our opinion (Lane, 1986; Lane, Kennedy, & Jones, 1986), one of the chief problems in quantifying soldier performance in general is the lack of reliability in the criterion tasks. This position is not new and has been documented since at least the pre-1955 literature where military operational performance measures were shown to be lacking in reliability. One conclusion stated: "it has been possible to make

measures objective enough...only to find that the key source of difficulty was not in errors of measurement, but in erratic day-to-day fluctuation of performance" (Miller, 1947, p. 353).

To circumvent the problems which hinder development of a quantitative definition of soldier performance due to exposure to irritant gases, we propose linkage of two methodological approaches: Surrogate Measures and Dose Equivalency.

1. Surrogate measures (Kennedy, Lane, & Kuntz, 1987) are those which are related to, or predictive of, a construct of interest but are not direct measures of the construct. Often they are obtained by measuring performance on demonstrably stable and highly reliable performance test batteries. Thus, performance changes on the stable and reliable tests are used to infer changes that would occur on the construct/operational performance of interest. In the present work, the Essex Automated Performance Test System (APTS) served as the surrogate measure. Tests of the APTS battery can be linked to the Armed Services Vocational Aptitude Battery (ASVAB) which in turn is related to operational performance. We discuss this in more detail below.

2. Dose Equivalency (Kennedy, Baltzley, & Osteen, 1988) is a strategy which advocates calibrating performance deficit on common tasks against an indexing agent. Then the same tasks can be administered in connection with exposure to other agents and performance changes indexed or calibrated against the indexing agent. It has been shown elsewhere that alcohol induced deficits can provide a useful interpretive description for comparison of the effects of psychoactive drugs on driving (O'Hanlon, Brookhuis, Louwerens, & Volkerts, 1986) and when comparing several different pharmaceuticals for side effects (Klein, 1972). However, these comparisons were conducted from findings in the literature rather than from studies specifically designed to develop a scientific program to study the problem. We favor using as an indexing agent, the global depressant ethyl alcohol. We believe that the choice of alcohol is justified by the considerable body of previous literature on the performance deficits produced by this agent, and by the practical problems (e.g. DWI) occasioned by the widespread use of alcohol.

The purpose of this present effort was to demonstrate the sensitivity of APTS to an indexing agent and to link changes on the APTS induced by the indexing agent to operational performance. In other words, work was performed to investigate the utility of surrogate measures and dose equivalency methods for the purpose of characterizing soldier responses to irritant gases.

#### Reliability and Operational Measurement

In studying the effects of irritant gases or any other agent on operational performance, we believe that the chief hindrance would be the lack of reliability of the operational performance measures, although there are other problems (e.g., lack of stability and real-time data reduction). The consequence of low reliability can be seen in the well-known correlational form of the Cauchy-Swartz inequality shown in Equation (1)

$$r_{xy} < [(r_{xx})(r_{yy})]^{1/2} \quad \text{Equation (1)}$$

where  $r_{xy}$  is the predictive (obtained) validity,  $r_{xx}$  is the reliability of the predictor,  $r_{yy}$  is the reliability of the criterion. The inequality states very simply that validity is limited by the reliability of both the predictor and the criterion, such that low reliability in either variable x or variable y substantially limits the possible relationship between the two.

Insufficient attention to reliability can lead to reduction of statistical power, higher sample size requirements, increased cost of experiments, and when hazard or discomfort is involved, human use problems. For instance, the true predictabilities of operational criteria from paper-and-pencil aptitude tests are often misinterpreted because of low criterion reliability. The reliability of operational measures may be improved from  $r = 0.20$  to  $r = 0.30$ , at great expense, but predictor reliability might go from  $r = 0.70$  to  $r = 0.90$  with much less investment. The relationship in Equation (1) suggested to us a focus on developing highly reliable measure sets such as may be obtained with microcomputer-based mental acuity tests (Kennedy, Wilkes, Dunlap, & Kuntz, 1987) which are separate from the operational criteria, but highly similar to the criteria in skill requirements. If the measures correlate well with the criteria, and behave similarly under changing task conditions, perhaps they could be used in place of the criteria; for example, as a surrogate in the case of assessing fitness for duty, a highly reliable measurement set of basic psychomotor and cognitive functions (e.g., relevant tests from the APTS) could be used to assess the operational criteria because the sets would be tailored to skill requirements.

#### Surrogate Measurement

We do not believe that combat performances, which occur in battle conditions, can meaningfully be modeled unless human performances can be adequately measured. Operational performances per se cannot be "adequately measured" because they tend to be unreliable. Surrogate measurement is offered as a technique to offset these problems. Surrogate measures are those which are related to or predictive of real-world performances but are not actual measures of the performance per se. In our plan, surrogate measures are composed of tests or batteries that exhibit five characteristics:

1. Stable so that the "what is being measured" is constant;
2. Correlate with the operational performance;
3. Sensitive to the same factors that would affect performance as the performance variable would;
4. More reliable than field measures; and
5. Involve minimal training time.

Surrogate measures differ from conventional performance measures in that tests need not involve operations in common with the performance measures, only components or factors in common. They also differ from "synthetic" work where tulerimia effects were examined for AMRDC several years ago (Morgan & Alluisi, 1972) or "job samples" (Eaton, Johnson & Black, 1980) because the surrogate requires minimal practice and is easier to score. However, surrogate approaches have other characteristics in common with these

techniques. Given the great difficulty of obtaining reliable enough field measures to carry out stressor sensitivity studies on an operational task itself, the case for using a surrogate is strong. A large portion of variance on extremely complex tasks can be predicted from performance on relatively simple tests. An external test or battery though cannot be as "valid" as the measure itself from a practical standpoint, but from a statistical standpoint a "surrogate" test can have more of the true variance of field performance because its reliability can be much greater.

One candidate for a surrogate would be the Armed Services Vocational Aptitude Battery (ASVAB). This is the test employed by the uniformed services to assess the mental aptitudes of prospective recruits. Scores obtained are used to determine eligibility for various military occupational specialties based on construct validity and continuing programs of empirical studies (Simms & Hyatt, 1981). The tests of the ASVAB have considerable content validity, some subtests sampling knowledge skills which are purportedly necessary for various occupational groups, and the others testing for aptitudes and abilities which could form the substrates of various tasks which make up military jobs. Analysis of military jobs through formal task analyses for purposes of task description (Carter & Biersner, 1987) and for aggregation of military occupational specialties (Carter & Biersner, 1982) have shown that the ASVAB measures characteristics central to performance of military tasks.

Validation studies include training performances at military formal schools (Booth-Kewley, 1984; Dunbar & Novick, 1985; Campbell (ED), 1988; Whitmarsh & Sulzen, 1989; Moreno, Wetzel, McBride, & Weiss, 1984) as well as operational performance studies (Wise, McHenry, Rossmeissl & Oppler, 1986; Zeidner, 1987). In at least one case (Wallace, 1982) performance during war games with tank forces performances were correlated with subtest scores from the ASVAB better than with any other variable in the study.

There is no single score or sets of scores which more consistently correlate with military on-the-job performance than the ASVAB, and so it has the requisite properties of a surrogate as described above, except that the ASVAB is not meant to be administered repeatedly (McCormick, Dunlap, Kennedy & Jones, 1983). Because the ASVAB is long (3.5 hours) and can only validly be administered once or twice in a six month period, it is impractical for usage in repeated measurement experimentation for purposes of indexing agents, treatments or environmental stresses which might disrupt military performance. However, if it could be shown that the ASVAB was highly correlated with a repeated measurement test battery, one might consider substitution of the repeated measurement tests to index performance decrements from various treatments like irritant gases and then by the principle of transitivity (things equal to the same thing are equal to each other) link changes in the surrogate with changes in the operational performance about which one wished to make statements. This logic using the APTS is shown in Figure 1.

#### Dose Equivalency

Dose Equivalency is a strategy used in conjunction with surrogate measures in order to quantify degradation of operational performance. The way that dose equivalency works is that an indexing agent(s) and a set of target performance tasks are selected. Then graded "dosages" of the indexing agent

## SURROGATE MEASUREMENT

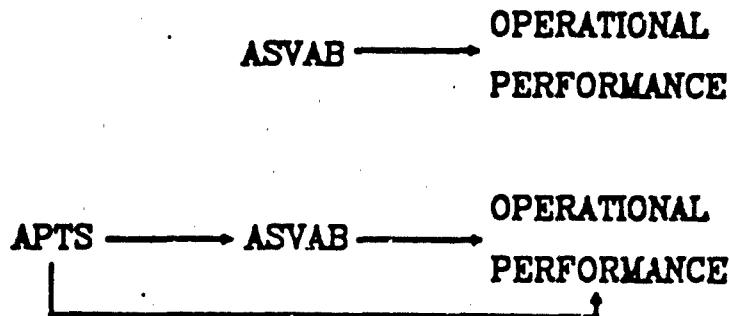
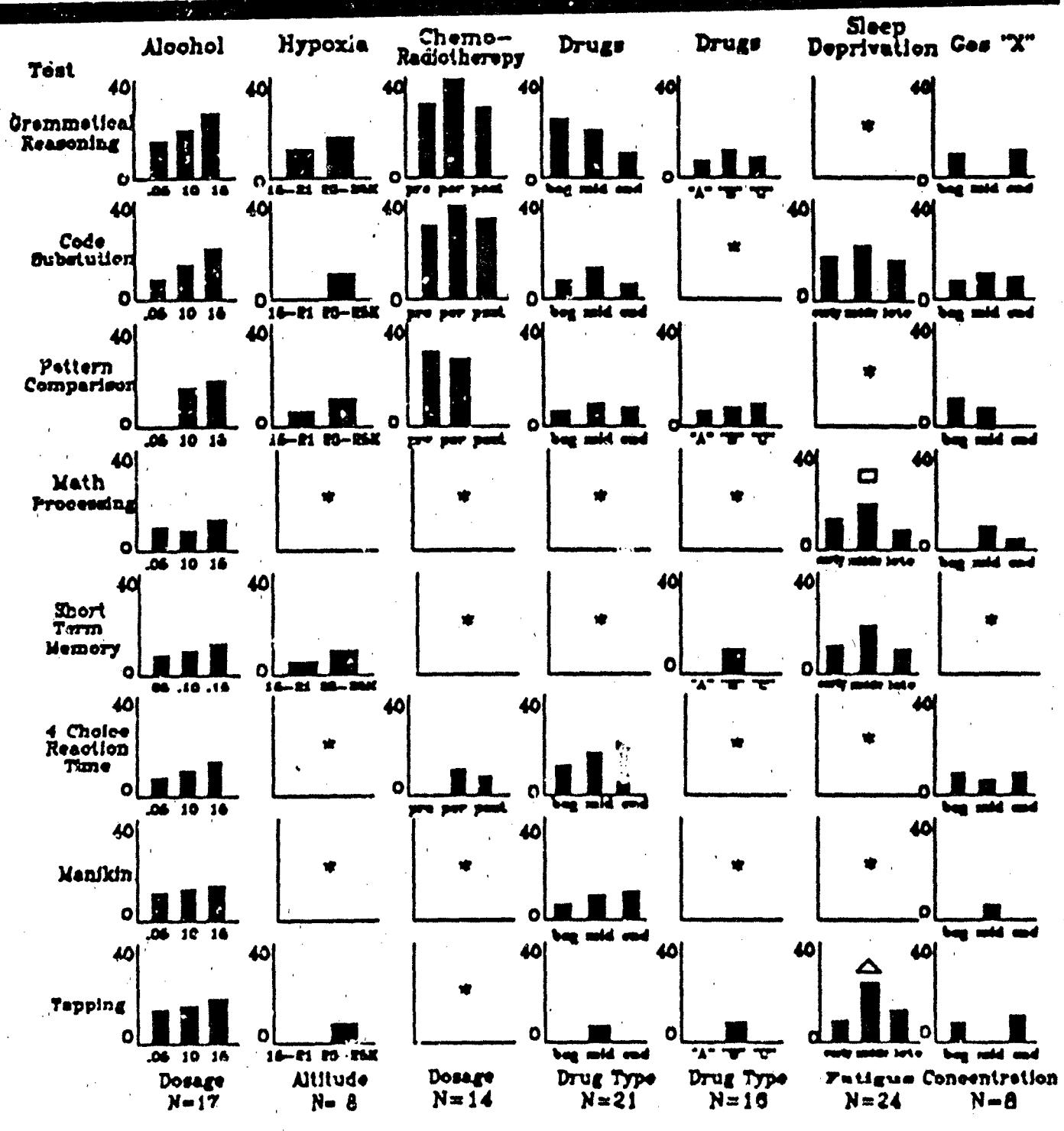


Figure 1. Use of Surrogate Measures (APTS and ASVAB) to Predict Operational Performance

are administered and performance decrements as a function of the indexing agent are marked or calibrated against the various dosages. One is left with a functional relationship between an agent and performance(s). These then become the indexing agent and the performances become the anchors against which other agents (in this case, irritant gases) or performances (in this case operational performances) are ultimately marked. So far as we know, this strategy has never been deliberately applied in any study but the one we conducted using different dosages of alcohol for the National Science Foundation (NSF) (Kennedy, Baltzley, Lane, Wilkes, & Smith, 1989), although the approach is logically implicit in many studies in the scientific literature.

Because several other experiments have been conducted with the same APTS tests, under essentially the same paradigm, it is possible to compare quantitatively the losses in performance due to different treatments (e.g., drugs, fatigue, psychological stress) with those due to alcohol. One may then describe the size of effect (i.e., the loss) in one environment (e.g., an antihistamine) with what was obtained under controlled conditions with two or three ounces of alcohol. Note that this technique does not imply that the mechanisms are the same with the two agents -- only that in terms of effect size, similar performance outcomes occur. Several previous studies which are part of what we consider our "APTS data base" can be compared to illustrate the dose equivalency notion. These have been summarized in Figure 2 which shows the average decrements in performance on eight APTS tests over seven disparate treatments. Information available from an earlier study on four different blood alcohol levels, carefully and accurately measured (e.g., all tests showed effects), demonstrated the feasibility of the approach (Kennedy, Wilkes, & Rugotzke, 1989). The other studies shown in the figure, although employing a minimal number of subjects, clearly point out the utility of making these comparisons (e.g., Calkins, 1989; Kennedy, Dunlap, Sandaret, Smith, & Houston, 1989).



\* Not Done  
 ▲ Tracking Test  
 □ Simple Addition

Figure 2. Decrement (Percent Loss in Performance) on Eight Mental Tests over Seven Disparate Treatments

## WORK CARRIED OUT

In Phase I, work was performed to investigate the utility of surrogate measurement and dose equivalency methods for the purpose of characterizing soldier responses to irritant gases. The specific tasks performed under Phase I are listed below.

- o Select indexing agent
- o Review literature on human and animal models for candidate agent
- o Select APTs subtests with relevance to military jobs
  - Review of Task Analysis
  - Demonstrate the validity of the APTs relative to the AEVAB
- o Administer indexing agent (alcohol) to experimental sample
- o Formulate the quantitative dose equivalency model

## RESULTS OBTAINED

### Selection of Indexing Agent

Orally administered ethyl alcohol was selected as the indexing agent in this project for several reasons. First, alcohol is known to be a global depressant, having wide-ranging and well-documented impacts on performance and operational readiness. A considerable body of experimental data exist regarding performance decrements occasioned by alcohol, and because of the ubiquitous problem of individuals operating vehicles and other dangerous equipment under the influence of alcohol, much research has been directed to the identification and calibration of what are to be considered "safe" and "unsafe" doses of this agent. Equipment and assay procedures are readily available for calibrating both blood alcohol levels (BAL) and more easily obtained estimates of BAL from alcohol detected in expired breath (breathalyzer). Finally, because alcohol is widely used, it is feasible to administer this agent to male subjects who, by self-report, use alcohol to a moderate degree, thereby obviating potential threat to the volunteers and meeting requirements for ethical treatment of subjects in human experimental research.

### Review of Literature Regarding Alcohol and Performance

Prior to selecting alcohol as an agent, the literature on alcohol and its effects on humans was searched for information. We were aware that the literature would be extensive. For example, there are well over 300 books in the card catalogue of the average library, several journals solely devoted to the subject and annual meetings with published symposia. These imply the field of study is moving very fast. However, we were purposeful in our review. We sought experimental support for (or against) alcohol as a suitable indexing agent for application of a dose equivalency experimental program to provide quantitative definition of soldier performance degradation from irritant gases. Key technical issues for us were the management of the agent as a stimulus for humans (viz., availability, benignity as a treatment agent, extent of medical coverage required, safety), available literature in scientific form, and ease with which the dosage could be calibrated. On these counts we already knew that alcohol was largely suitable, but there were additional issues such as strength of effect of the treatment, monotonic nature of the human response, stability of the treatment effect despite

extended practice, and others. Consequently, our review of the alcohol literature was eclectic and selective.

A general background on performance impairment by alcohol is contained in chapters by Tarter and Edwards (1985) and by Ray and Ksir (1987). In these studies and elsewhere, most performances were shown to be degraded as a function of dosage (e.g., Dunlap, Kennedy, Lane, Turnage, & Latimer, 1989; Jex, McRuer, Allen, & Klein, 1974) where there is an increased proportion of subjects with reduced scores as a function of the blood alcohol level varying from .01 to .15. With alcohol dosages as low as .05-.08 BAL, Robinson and Peebles (1974) were able to produce reliable performance decrements depending on the amount of data collected and the reliability of the measures. These studies indicate that the effect of alcohol is monotonic and can be sizable.

Much work has also been accomplished with respect to alcohol dose and impaired driving performance from which translation to military occupations (tanks, trucks, fighting vehicles) could be expected to be made directly. For examples see O'Hanlon & deGier (1986), Mitchell (1985), and Ziporyn (1985). Also of importance in a military context is the research on the effects of alcohol intoxication on skills essential to piloting aircraft (Wise, 1980). Studies regarding the Multitask Performance Battery (a battery devised to simulate the reaction time, detection skills, and motor tracking believed to be critical to the pilot's job) to alcohol are provided by Collins and Chiles (1980) and by Collins, Mertens, and Higgins (1987). Effects of alcohol on pilot performance in a flight simulator were studied by Ross and Mundt (1988). Examples of alcohol produced decrements in more specific tasks are provided by Chiles and Jennings (1970) (arithmetic and compensatory tracking), Maylor, Rabbitt, and Connolly (1989), Rundell and Williams (1979) (four-choice reaction time), and Ryback (1970) (short-term memory). Decrements in skilled performance on complex cognitive/motor tasks are reported by Tarter, Jones, Simpson, and Vega (1971).

Alcohol is proposed in this work as an indexing agent which can be employed to study human performance effects and then used as criteria for comparison to similar performance changes with irritant gases. The literature review revealed that a related notion has been proposed, but not carried out experimentally, in two other places. The first, a study by Klein (1972), used existing data from previous investigations and described, with some success, the performance decrement from various drugs in terms of alcohol dosage. In the second (O'Hanlon et al., 1986), a benzodiazepine (Lorazepam), which could be used by drivers, was compared to differing alcohol dosages against a single measure (steering reversals) taken over a 100 km course. Both of these studies imply that a dose equivalency model could be successful.

An important variable not often recognized in the studies of alcohol and other drugs on performance is the effect that practice may have on the task being used to index the drug effect. Drew, Colquhoun, and Long (1958), in a study on alcohol and reaction time, point out that changes in performance take place during practice and this and other methodological issues could impact on alcohol studies in general. However, it was also shown that practice per se cannot be used to remove an alcohol effect if that same subject were studied in the unpracticed mode (Maylor & Rabbitt, 1988). A series of studies (Maylor & Rabbitt, 1987, 1988) has compared alcohol treatment changes with practice effects. These studies show that the treatment effect of alcohol does not

disappear with practice and so the effect of alcohol is stable. Provided the tests of the APTS battery exhibit stability also, then it will be possible to arrange a protocol of repeated measures studies where each subject is his own control. It is well known that extreme statistical power can be achieved by using within-subject designs (Cohen, 1977) and because of the reported stability of the effect (Maylor & Rabbitt, 1987, 1988) the same subjects can be used over many experimental treatments. Indeed, it may also be possible to calibrate such subjects (with and without alcohol) and employ them repeatedly in exposures to various gas mixtures.

In summary, we are aware there are other possible candidates for an indexing agent and several of these we considered (viz., nitrogen, oxygen deprivation, CO), but none of these is as well researched nor possesses the stimulus or treatment properties as does alcohol.

#### Selection of APTS Tests with Relevance to Military Jobs

##### Review of Task Analysis Relating APTS to Requirements of Operational Performances

One technique to examine the linkage between APTS and operational performance is task analysis via one of the acceptable methodologies (e.g., the PAQ of McCormick, Jeanneret, & Mecham, 1969). We report here previous work which compared abilities tested by APTS tests to the requirements for those abilities in various NASA mission specialist tasks was sought (Jeanneret, 1988). In this work a generic position was selected for study. This position, the job of Aerospace Payload Specialist, covered the range of anticipated duties of astronauts and others assigned to a space station. For this effort, the task was decomposed following the approach of the Position Analysis Questionnaire (PAQ). The PAQ is perhaps the most widely used example of such an analysis instrument which has the capability to describe jobs in mental attributes. The PAQ is a structured job analysis questionnaire that can be used for analyzing jobs of many different types. It consists of six major divisions: (1) information input, (2) mental processes, (3) work output, (4) relationships with other persons, (5) job context, and (6) other job characteristics.

The preliminary results of the PAQ analysis yielded a set of behavioral job dimensions which characterized the content of these positions and permitted estimation of requirements for effective job performance. These elements are shown to converge with APTS test factors in matrix form as shown in Tables 1 and 2. Following this same methodology in future work, test batteries can be assembled to map onto particular military occupational specialties which are the targets of interest.

##### Validity of Performance Battery via Regression on the ASVAB -

In a previous study (Kennedy, Baltzley, Dunlap, Wilkes, & Kuntz, 1989); a synthetic ASVAB was administered to a sample of college students. Thirty-seven subjects (16 women, 11 men) were tested on the APTS battery and the synthetic ASVAB. These data were examined in the present effort to select APTS subtests related to the ASVAB that would be used in the alcohol dose equivalency study. Subjects initially completed the synthetic ASVAB which required three hours of testing. They then completed seven replications of

TABLE 1. ATTRIBUTE BY MICROCOMPUTER PERFORMANCE TEST MATRIX

Attributes	Performance Components	Test-Battery Components	Time Sharing	Selective Attention	Ideational Fluency	Convergent Thinking	Short-Term Memory	Reason	Time	Code Substitution	Alphanumeric Vigilance	Complex Counting	Fits Histogram	Flying Landbolt C	Mathematical Processing	Continuous Recall	Item Recognition	Matrix Rotation	Matrix Inversion	Item Order	Visual Scanning	Associative Memory	Power of Hand	Short-Term Memory
Intelligence (G)																								
Verbal Comprehension																								
Numerical Computation																								
Arithmetic Reasoning																								
Convergent Thinking																								
Short-Term Memory																								
Ideational Fluency																								
Selective Attention																								
Time Sharing																								
Visual Form Perception																								
Perceptual Speed																								
Spatial Visualization																								
Near Visual Acuity																								
Eye-Hand Coordination																								
Simple Reaction Time																								
Response Integration																								
Rate Control																								
Sensory Alertness																								
Finger Dexterity																								

TABLE 2. COMPARISON OF ATTRIBUTES MEASURED BY APTS WITH  
PREDICTED ATTRIBUTES FROM PAQ DATA FOR SPECIALTY FUNCTIONS

<u>Attributes Measured by APTS</u>	<u>Attributes Predicted from PAQ Data to be Important to Performance of Payload Specialist</u>
Verbal Comprehension	Verbal Comprehension
Numerical Computation	Numerical Computation
Arithmetic Reasoning	Arithmetic Reasoning
Convergent Thinking	Convergent Thinking
Intelligence (G)	Intelligence (G)
Short-Term Memory	Short-Term Memory
Ideational Fluency	--
Selective Attention	Selective Attention
Time Sharing	--
Visual Form Perception	Visual Form Perception
Perceptual Speed	Perceptual Speed
Spatial Visualization	Spatial Visualization
Near Visual Acuity	Near Visual Acuity
Eye-Hand Coordination	Eye-Hand Coordination
Simple Reaction Time	Simple Reaction Time
Response Integration	--
Rate Control	Rate Control
Sensory Alertness	Sensory Alertness
Finger Dexterity	Finger Dexterity
	Dealing with Things/Objects
	Processes/Machines/Techniques
	Scientific/Technical Activities
	Pressure of Time
	Attainment of Set Standards
	Working Under Specific Instructions
	Tangible/Physical-End Products
	Sensory/Judgmental Criteria
	Measurable/Verifiable Criteria
	Manual Dexterity
	Arm/Hand Positioning
	Arm/Hand Steadiness
	Closure
	Spatial Orientation
	Aesthetic Judgment
	Color Discrimination
	Movement Detection
	Depth Perception
	Far Visual Acuity
	Tactile Acuity
	Kinesthesia
	Long-Term Memory
	Divergent Thinking
	Mechanical Ability

the APTS battery within a three week period. The synthetic ASVAB and APTS tests are described below.

#### Materials

Synthetic ASVAB. Because the subject sample was recruited from a college student population rather than a military group, actual ASVAB scores were not available nor was actual ASVAB testing feasible. Therefore, we studied the relationship between scores on a synthetic Armed Services Vocational Aptitude Battery (ASVAB) which was obtained from a book of facsimile tests (Steinberg, 1986) widely available in bookstores throughout the continental United States and used to practice for the ASVAB. This particular version had been compiled by a civil servant (Steinberg, 1986) who had been associated with ASVAB testing for several years. As in the original ASVAB, this battery is composed of 10 subtests: General Science, Arithmetic Reasoning, Word Knowledge, Paragraph Comprehension, Numerical Operations, Coding Speed, Auto & Shop Information, Mathematics Knowledge, Mechanical Comprehension, and Electronic Information. Like the true ASVAB, the test may be administered in 144 minutes; however, instructions and procedures significantly increase the total testing time. One combination of ASVAB subtest scores serves as the Armed Forces Quantifying Test (AFQT) which determines acceptance into a particular branch of the armed services. Other scores are also derived from the ASVAB and serve to identify aptitude and training placement. The true ASVAB test is regarded as a measure of general intelligence with both verbal and quantitative components. There are no known normative psychometric data for the facsimile test employed.

Microcomputer-based Assessment. APTS subtests used were selected based on previously demonstrated stability and reliability. Seven of the eleven tests selected for the core performance battery were from the APTS battery of an original set of 30 performance measures found statistically to be most suitable for repeated-measures applications. These were Pattern Comparison; Two-Finger and Nonpreferred Hand Tapping; Code Substitution; Simple Reaction Time; Grammatical Reasoning; and Manikin.

Four additional subtests were selected from the Unified Tri-Service Committee Performance Assessment Battery (UTC-PAB), which is similar to the Performance Assessment Battery (PAB) developed by the Walter Reed Army Institute of Research (WRAIR) (Thorne, Genser, Sing, & Hegge, 1983), but also contains tests from Navy (Naitoh, 1982) and Air Force sources (Shingledecker, 1984), and is composed of a variety of subtests which measure varying degrees of cognitive and visual-motor processing abilities. Test selection for that battery was by a tri-service committee of behavioral scientists. These subtests were Associative Memory, Recall, Math Processing, and Matrix Rotation. A description of each APTS and PAB subtest is provided in Appendix A.

#### Data Analysis

Means, standard deviations, and reliabilities for the 11 microcomputer tests which were examined in this study can be found in Table 3.

TABLE 3. MEANS, STANDARD DEVIATIONS, AND RELIABILITIES OF TEST MENU UTILIZED IN THE "ASVAB" STUDY

Test	Mean	SD	Reliability
Pattern Comparison	127.2	19.4	0.92
Grammatical Reasoning	46.3	13.3	0.94
Recall	83.6	44.2	0.96
Math Processing	132.7	19.1	0.89
Manikin	105.3	31.0	0.97
T F Tapping	40.8	7.8	0.98
Associative Memory	14.5	3.9	0.88
Reaction Time	335.7	101.8	0.86
Code Substitution	66.7	5.2	0.85
Matrix Rotation	81.3	23.2	0.90
Non-Pref. Tapping	34.3	9.0	0.97

The most dramatic findings depicted in the above table are the consistently high reliabilities of the battery subtests, but of course these tasks and tests were purposely selected for this characteristic. The smallest reliability above was 0.85, which in our judgment is sufficient for statistical power and differential purposes.

Scores on the performance battery were averaged across the seven trials and then correlated with the subscales and total score from the ASVAB. Cross-correlations between the battery subtests and the ASVAB scales are presented in the Table 4. The final column of the table gives the correlations of the subtests of the performance battery with the total of all ASVAB scales.

TABLE 4. CROSS-CORRELATIONS OF APTS' SUBTESTS WITH THE ASVAB

Subtest	ASVAB Sub Scale										
	GS	AR	WK	PC	NO	CS	AS	MK	MC	SI	TOTAL
Patt Comp	.61*	.54*	.54*	.53*	.42	.66*	-.19	.55*	.50*	.18	.82*
Gram Reas	.35	.27	.40	.49*	.35	.43	-.03	.47*	.41	.15	.57*
Recall	.29	.46*	.31	.52*	.20	.11	-.03	.49*	.21	.31	.36
Math Proc	.51*	.54*	.52*	.53*	.39	.61*	-.19	.54*	.36	.15	.82*
Manikin	.33	.41	.52*	.40	.05	.34	-.07	.29	.24	.24	.59*
T F Tap	.13	-.14	.41	.18	.12	.53*	-.43	-.13	.11	.00	.29
Assoc Mem	-.03	.02	-.14	-.07	-.05	-.39	.27	-.07	.18	.42	-.17
Rxn Time	-.43	-.45*	-.53*	-.36	-.68*	-.69*	.02	-.44*	-.41	-.11	-.71*
Code Sub	.26	.37	.29	.16	.41	.68*	-.08	.36	.38	-.02	.72*
Mat Rot	-.01	.38	.06	.14	.16	.22	-.22	.31	.23	-.04	.26
N P Tap	.21	-.01	.45*	.28	.03	.46*	-.38	.07	.15	.15	.38

With the exception of Auto-Shop and Electronics-Information, all other subscales of the ASVAB were significantly related to at least one of the subtests of the performance battery. Neither Matrix Rotation nor Associative Memory related significantly to any ASVAB subscale nor to the total, therefore, these particular subtests were eliminated from the surrogate battery to be employed in the alcohol dose equivalency study. Because Recall did not correlate significantly with the ASVAB total it too was dropped from the surrogate battery. Even though they did not correlate significantly with the ASVAB total, it was decided to keep the Tapping tasks because they consume very little time, and they index a type of performance relatively independent from the other measures. Also, it was thought that four choice reaction time might share more variance with the ASVAB than simple reaction time, we decided to change the format of that subtest. Finally, because we felt that memory is an important aspect of performance readiness, and were disappointed by the Associative Memory test, we decided to include the Sternberg Test of Short Term Memory in the surrogate battery to be used for the alcohol calibration data.

Next, multiple regression was used to examine the predictive power of the battery as a whole on the total ASVAB criterion. The multiple  $R$  was 0.94 ( $R^2 = 0.88$ ), and even when corrected for shrinkage, the multiple  $R$  was 0.88. This indicates that when shrinkage owing to the particular sample used is taken into account, 77% of the ASVAB variance is explained by performance on the battery subtests. Examining the pattern of beta weights, which is a somewhat risky way to consider usefulness of predictors in a battery, beta weights whose associated  $t$  values exceeded 2.0 were found for pattern comparison and for code substitution. Betas whose  $t$  values fell between 1.0 and 2.0 were for Non Preferred Hand Tapping, which supports the inclusion of these tests in the surrogate battery.

A second multiple regression analysis was conducted including the candidates surrogate performance subtests - those that would be used in the alcohol study - Code Substitution, Pattern Comparison, Grammatical Reasoning, Manikin, Math Processing, Two Hand Tapping, Non-Preferred Hand Tapping, and Reaction Time. The Multiple  $R$  was .92, indicating that we lost very little common variance with the ASVAB by using the shortened surrogate battery. Finally, it should be pointed out that all of these correlations are based upon averaged performance test scores; therefore by the Spearman-Brown relationship, they will overestimate the correlation that a single administration of the performance tests would show with the ASVAB. The corrected for shrinkage multiple  $R$  of the shortened surrogate battery with the ASVAB was 0.88. Using the Spearman-Brown prophesy formula,

$$R_1 = (kR_7) / [1 + (k-1)R_7] \quad \text{Equation (2)}$$

where  $R_1$  is the single administration correlation,  $R_7$  the correlation with the seven trial averages, and  $k$  equals 1/7, we estimate the correlation of a single administration of the surrogate battery with the ASVAB to be 0.51. Therefore, we expect that approximately 25% of the ASVAB variance is shared by a single administration of the surrogate battery, whereas percent of explained variance increases to 77% with the average of seven APTS administrations.

### Indexing Agent (Alcohol) Administered to Experimental Sample

Many of the technical details regarding methods, procedures, and safeguards in studying the effects of orally administered alcohol on APTS performance were worked out in previous research sponsored by the NSF and reported by Kennedy, Wilkes, and Rugotzke (1989).

#### Method

Subjects. Male students, 21 years of age or older, attending Casper College or the University of Wyoming, were recruited as subjects. A total of 42 students were initially briefed regarding the study. Thirty-one of those addressed volunteered for participation. From those volunteering, a pool of acceptable candidates was established. Acceptable candidates were those indicating some, but not excessive, experience with alcohol, no past history of chronic dependency of any type, good general health, and indications of low risk for future alcohol-based problems. The typical subject identified himself as having "moderate" previous experience with alcohol (Cahalan Volume-Variability Scale  $M = .34$ ,  $SD = .28$ ), and at low risk for future problems with alcohol (Iowa Scale of Preoccupation with Alcohol median category = 5 and range = Categories 5 to 3). Students indicating problem family histories of chemical abuse/dependency and/or past personal histories of chemical abuse/dependency were advised not to participate. Initially, 22 subjects were randomly selected from the pool to participate. Two of the subjects selected for participation elected to withdraw from the study. The 20 subjects completing the study ranged in age from 21 to 42 ( $M=27.3$ ,  $SD=6.5$ ) with weights from 140 to 310 pounds ( $M=176.5$ ,  $SD=39.5$ ).

#### Experimental Design

Each subject served as his own control with performance measures completed both prior to and after treatment. Subjects were assessed with the Automated Performance Test System (APTS) (Essex, 1986) prior to ingesting alcohol and at subsequent prescribed BALs. BAL was closely monitored with breath testing procedures. When possible, data were collected at BALs of 0.150, 0.125, 0.100, 0.075, and 0.050. One further measure with the APTS was collected the morning following alcohol ingestion. Double-blind procedure and placebos were not employed and both subjects and experimenters were fully aware of the experimental condition.

a. Independent Variable-Blood Alcohol. Blood alcohol concentration was manipulated by administering fruit punch mixed with grain alcohol (95% alcohol). One drink was premixed for each subject, with subject weight and estimated body fat determining the proportions of alcohol. Proportions of grain alcohol and punch were combined to raise a subject's BAL slightly above the 0.150 level. The amount of grain alcohol in milliliters was calculated using a condensed version of the Widmark Equation: 1 ml of Grain Alcohol =  $(200/190) (30) (0.13)$  (weight in pounds with target BAL + 0.05). Breath monitoring for BAL was initiated approximately 30 to 45 minutes after a subject had finished drinking. Monitoring continued until the peak alcohol concentration had been attained and was further monitored on the descending limb of the BAL curve to prescribed testing levels. Attainment of a prescribed BAL level ( $\pm 0.005$ ) signalled employment of APTS testing. Breath alcohol was analyzed using two Intoximeter 3000 breath testing units.

b. Dependent Variable-APTS Performance. Performance was assessed with the APTS. Development of the APTS was based on the concepts and empirical findings of the Performance Evaluation Test for Environmental Research (PETER) program (Bittner, Carter, Kennedy, Harbeson, & Krause, 1986), and is comprised of three subsystems: (1) hardware, (2) test programs, and (3) system control. The APTS provides for microbased repeated measures of human performance while under the influence of various environmental or experimental agents. The reliability, stability, factor structure, and sensitivity of the measures are discussed inter alia and hardware specifications appear in the Apparatus section.

#### Materials

Various paper-and-pencil and computer software materials were employed in screening and assessing the individual subjects. These materials are identified and discussed below:

1. Personal Information Questionnaire (PIQ). The PIQ was specifically developed for use in a previous study (Kennedy, Wilkes, & Rugotzke, 1989) performed by Essex. The questionnaire assesses the personal characteristics and histories of potential research subjects. The information provided partial basis for the selection of students into the final subject pool. Relevant information concerning weight and general health were addressed. The PIQ was administered once during the latter half of subject solicitations. A copy of the PIQ may be examined in Appendix B.

2. Current Health State Questionnaire (CHSQ). The CHSQ questionnaire was specifically developed for use in a previous study (Kennedy, Wilkes, & Rugotzke, 1989). The questionnaire assesses a subject's state of health immediately prior to the administration of an experimental alcoholic treatment. Information collected with the CHSQ facilitated alcohol treatment preparations and identification of subjects not currently fit for participation. The CHSQ was administered immediately prior to ingesting alcohol. A copy of the CHSQ may be examined in Appendix C.

3. Iowa Scale of Preoccupation with Alcohol (IS). The IS was previously developed by Mulford and Miller (1961) and consists of 12 behaviorally defined statements scaled to distinguish five levels of drinking behavior. Three self-descriptive statements are associated with each of the first four levels of drinking behavior. The fifth level is reserved for individuals not responding affirmatively to items associated with the previous four levels. Subjects respond to the IS by indexing statements applying to them. Agreement with any two items within a level identified a subject as to "type of drinker." Subjects identifying levels I and II are classified as "alcoholic drinkers" (Mulford & Miller, 1961, p. 28). Subjects identifying at levels III and IV are simply classified as drinkers. Subjects identifying at level V are not classified as drinkers. The IS was employed in determining the potential risk associated with participation in the study. The scale was administered once in conjunction with the PIQ and was an important measure in eliminating candidate participants from inclusion in the subject pool. A copy of the IS questionnaire may be reviewed in Appendix D.

4. Cahalan Volume-Variability Scale (V-V). The V-V had been previously developed (Cahalan, Cisin, & Crossley, 1969) to assess alcohol consumption.

Assessment was based on students' self-report of the quantity, frequency, and variability of alcoholic beverage consumption over a standard period of time. Subjects respond to the V-V scale by indicating how often, and how much, they consumed of wine, beer, liquor or any type of alcoholic beverage. The average daily volume is estimated by multiplying the frequency of consumption of each beverage by the estimated quantity of the beverage per occasion. Variability for each of the three volume groups is established by subdividing each volume group according to the number of drinking occasions per month (Calahan et al., 1969, pp. 213-215). Based on the average daily volumes, as well as daily variabilities in alcohol consumption, individuals are classified according to eight identifiers ranging from "High Volume, High Maximum" to "Abstainee." The V-V was administered once in conjunction with the PIQ and IS, and was an important measure in eliminating totally inexperienced and extremely heavy users of alcohol from inclusion in the subject pool. A copy of the V-V questionnaire may be reviewed in Appendix E.

5. Informed Consent Form (ICF). The ICF was developed for use in this study. The form was divided into two sections with the first providing an in depth description of the research procedure and obligation and the second consisting of review copies of the PIQ, CHSQ, IS, and V-V. Subjects indicated their understanding of research procedures and obligations and willingness to complete the questionnaires by signing and dating the form. A copy of the form was retained by each subject for reference purposes and originals were maintained in a confidential file with other pertinent subject information. A facsimile of the ICF appears as Appendix F.

6. APTS Subtests. As described above, APTS tests were selected because of their demonstrated or expected correlation with the ASVAB. Each of the subtests have been researched and commercially developed by Essex Corporation, Orlando, Florida. Each subtest had been previously evaluated relative to repeated-measures selection criteria. These criteria are fully discussed elsewhere (Kennedy, Wilkes, Lane, & Homick, 1985; Kennedy, Wilkes, Dunlap, & Kuntz, 1987) with stability and reliability paramount. The subtests have demonstrated reliabilities  $\geq 0.707$ , with mean, standard deviation, and differential stability achievable in 8 to 12 minutes of practice (Kennedy, Wilkes, Lane, & Homick, 1985; Wilkes, Kennedy, Dunlap, & Lane, 1986; Wilkes, Kuntz, & Kennedy, 1987). Collectively, the nine subtests have been demonstrated to identify four separate factors (Lane & Kennedy, 1988) including: motor speed; symbol manipulation/reasoning; cognitive processing speed; and speed of response selection. Table 5 indicates the subtest order, practice, trial, and battery time. The subtests are described in detail in Appendix A.

#### Apparatus

The technical equipment/instrumentation used is discussed below:

1. NEC PC 8201A. Microcomputer testing was conducted with eight NEC PC8201A microprocessors. The NEC 8201A is configured around an 80C85 microprocessor with 64K internal ROM containing BASIC, TELCOM, and a TEXT EDITOR. RAM capacity may be expanded to 96K onboard, divided into three separate 32K banks. An RS-232 interface allows for hook-up to modem, to a CRT or flat-panel display, to a "Smart" graphics module, to a printer, or to other computer systems. Visual displays are presented on a 8-line LCD with 40

characters per line. Memory may be transferred to 32K modules with independent power supplies for storage and mailing. The entire package is lightweight (3.8 lbs), compact (110W X 40H X 130D mm), and fully portable with rechargeable nickel cadmium batteries permitting up to four hours of continuous operation. Table 6 abstracts the technical features of the system which are more fully described in NEC (1983) and Essex (1985).

TABLE 5. APTS SUBTEST ORDER, PRACTICE,  
TRIAL, AND BATTERY TIME

Subtasks in Order of Battery Presentation	Trials/ Battery	Practice Time	Trial Time	Total Task Time in a Battery Less Practice
NPT	2	10 <sup>a</sup>	10	20
GR	1	30	90	90
MP	1	30	90	90
CS	1	30	90	90
PC	1	30	90	90
MK	1	30	90	90
STM	1	30	90	90
RT	1	30	90	90
THT	2	10	10	20
<b>Totals</b>		<b>230</b>	<b>650</b>	<b>670</b>

<sup>a</sup> All times reported in seconds

NPT = Nonpreferred-Hand Tap

GR = Grammatical Reasoning

MP = Math Processing

CS = Code Substitution

PC = Pattern Comparison

MK = Manikin

STM = Short-Term Memory

RT = Reaction Time-4 Choice

THT = Two-Hand Tap

2. Intoximeter Model 3000. The Intoximeter Model 3000 breath analyzer is an instrument that estimates alcohol concentrations in the blood by analysis of breath. It employs the well-established principles of nondispersive infrared (NDIR) molecular absorption. Each compound in the breath absorbs infrared energy in a combination of absorption bands at frequencies unique to that compound. The position of these absorption bands do not change. However, the amount of energy absorbed at a given absorption band will vary in direct relation to the number of molecules within a fixed path, i.e., the concentration of alcohol in the sample chamber.

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TABLE 6. NEC 8201A TECHNICAL SPECIFICATIONS

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FEATURES	SPECIFICATIONS
SIZE	30 CM (11 IN) X 22 CM (8.25 IN) X 6 CM (2.5 IN). 1.7 KG (3.8 LBS)
CPU	80C85 (CMOS VERSION OF 8085) WITH 2.4 MHZ CLOCK
ROM	32K (STANDARD) - 128K (OPTIONAL)
RAM	24K (STANDARD) - 96K (OPTIONAL)
KEYBOARD	67 STANDARD (10 FUNCTIONS, 4 CURSOR DIRECTIONAL AND 58 ADDITIONAL)
DISPLAY	19 CM (7.5 IN) X 5.0 CM (2.0 IN) WITH REVERSE VIDEO OPTION. MAY BE CONFIGURED AS EITHER A 240 X 62 ELEMENT MATRIX OR 40 CHARACTERS X 8 LINE DISPLAY
INTERFACES	1 PARALLEL (CENTRONICS COMPATIBLE) AND 3 SERIAL (RS232C AND 6 & 8 PIN BERG) JACKS
POWER SUPPLY	4 AA NONRECHARGEABLE BATTERIES, OR RECHARGEABLE NICKEL-CADMIUM PACK, OR AC ADAPTER 50/60 Hz @ 120 VAC, OR EXTERNAL BATTERY SYSTEMS (e.g., 8 AMP HR)

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The analyzer uses a narrow band pass interference filter to isolate an absorption band at 3.45 microns, one of the strong absorption bands for alcohol. A heated element sends infrared energy through a two-chambered gas sample cell of fixed path length. With no absorbing gas in the sample half of the cell, the energy of the sample beam is ratioed against the energy passing through the reference half of the cell. The ratio is used to set and establishes the zero set point. Alcohol in the sample cell will absorb some of the sample beam energy. The amount of energy attenuated is proportional to the number of alcohol molecules in the sample cell. The ratio is sent to a microprocessor which calculates the blood alcohol concentration. The results are printed, displayed, and stored in memory.

Research Personnel

The complexity of the study necessitated the use of a team of researchers with various areas of experience and expertise. Each of the research specialties is described below:

1. Performance Assessment Specialist (PS). One individual was employed for the purpose of collecting microbased performance measures. The PS was also responsible for administering the CHSQ at the beginning of each data

collection session. The PS was selected for his previous experience with human performance research and familiarity with the microbased assessment system.

2. Treatment Preparations and Breath Analyses Specialists (TB). Two individuals were employed for the purposes of determining each subject's immediate suitability to participate during a particular data collection session (based on responses to the CHSQ), preparing alcohol dosages based on body weight, conducting breath alcohol testing, and analyzing Intoximeter breath data. The TBs were selected for expertise developed in similar activities as alcohol awareness training specialists under the auspices of the State of Wyoming Department of Chemical Testing Program and previous research experience involving alcohol and performance.

3. Protocol Directors (PD). Two individuals were employed to direct subjects from treatment application through the various dependent measures data collection procedures. Initial monitoring of breath data, behavior management, and time/order tracking of each subject were important component duties. The individuals were selected for previous experience with police work as well as research and data collection expertise.

4. Supernumerary Personnel (SP). Other individuals were employed for the purposes of supervising subjects while intoxicated, driving subjects to and from the research site, and monitoring residence halls. Services of a Medical Doctor were also retained during the data collection sessions. Medical services were unneeded, although available, over the entire course of the study.

#### Procedure

1. Subject Solicitation Selection. Adult male Casper College and University of Wyoming students were solicited for research participation. Potential subjects were recruited from classes with high male enrollment (e.g., electronic technology, engineering) and large enrollments (e.g., general biology and general psychology). Candidate subjects were also recruited campus-wide with informational posters and advertisements in the college newspaper. Individuals interested in learning more about the study were invited to attend a group informational meeting or were provided with an individualized briefing. During the meeting, research procedures and subject obligations were reviewed in detail. Each potential subject was provided with an eight-page outline titled "Informed Consent Form: Characterizing Soldier Response to Stressors" (Appendix F). The outline specifically addressed the following issues: (a) the purpose of the study; (b) the blood alcohol treatment levels including an indication that the maximum treatment level was equal to a BAL of 0.150, an amount greater than the State of Wyoming legal limit for operating a motor vehicle and capable of inducing a hangover; (c) the microbased performance measures; (d) the research design/procedures and resultant research participation obligations and personal time commitments; (e) the remuneration for participation (i.e., \$20/completed data collection session with a bonus for the fulfillment of all research requirement); (f) the personal information to be assessed with the PIQ, CHSQ, IS, and V-V questionnaires. Copies of the four questionnaires were attached and materials of a particularly sensitive nature were reviewed. Candidate subjects were further cautioned to consider a number of personally critical factors prior to

volunteering for participation. These factors drew attention to the importance of good physical and mental health: the absence of medical conditions likely to be exacerbated by alcohol (e.g., epilepsy, diabetes), necessary medications of an interactive nature with alcohol; past personal or family histories of drug/alcohol abuse; inability to comply with study procedures, scheduling and time obligations (special emphasis was placed on research obligations/requirements and were extensively reviewed); inexperience with alcohol and a required chronological age  $\geq 21$  years. It was emphasized that individuals should not consider volunteering if any of the various factors cited precluded participation. Questions were encouraged regarding any aspect of the study and clarification was provided. All individuals were thanked for their time and interest and those electing not to participate departed. These subject solicitation procedures ensured that each candidate subject was fully informed of the study procedures, obligations, potential dangers, and personal selection factors. Furthermore, individuals electing not to participate due to sensitive personal issues were unidentifiable from those unable to comply for more mundane reasons. Such procedures insured the participants' physical and psychological well being while preserving the personal dignity of each individual.

The candidate subjects demonstrating continued interest in research participation were asked to complete, date, and sign each of the previously reviewed personal information questionnaires (i.e., PIQ, CISQ, IS, and V-V). The candidates were informed that all questionnaire data would be available only to the research directors and would be coded and secured to ensure confidentiality. It was stressed that these data would not be available to the college administration or individual instructors. Candidates were required to acknowledge the research proceedings review and that they clearly understood the research purpose, design, and method. The ICF was then signed and dated by each prospective candidate and collected and filed by the researcher. Randomizing techniques for final subject selection were described and it was indicated that not all prospective candidates could participate. It was further emphasized that nonselection would be based on "chance" and could not be interpreted as an indication of lack of fitness for study participation. Lastly, it was emphasized that participation was totally voluntary and that terminating the study would not result in penalty, loss of earned benefits or jeopardy to college grading. The candidate subjects were thanked for their interest and informed that notification of selection for participation would be completed within the following one-week period. Information from the PIQ, IS, and V-V was then reviewed and assessed concerning subject selection criteria. Potential subjects were dropped from further consideration based on the following criteria:

- a. PIQ. Indication of poor general health, current medications known to interact with alcohol, and low tolerance to alcohol-induced illness.
- b. IS. A score on the IS resulting in classification in category I or II ("alcoholic drinkers," Mulford & Miller, 1961, p. 28).
- c. V-V. A score on the V-V resulting in indications of high volume consumption ( $M > 1.59$  drinks/day). Only individuals showing low ( $M = .00$  to  $.58$ ) or moderate volume ( $M = .59$  to  $1.49$ ) drinks/day were selected.

2. Subject Training. The primary purpose of training was to familiarize subjects with assessment procedure, practice the performance tests to asymptotic levels, and provide the researchers with pilot study insights. One to two weeks prior to data collection, subjects were required to practice the APTS battery.

The APTS battery was practiced for a minimum of 11 trials. Subjects practiced the microbased battery at the convenience of their personal schedules. Microprocessors were made available in a testing laboratory, on a daily basis, from 8:00 A.M. to 7:00 P.M. All subjects completed the required practice trials within two to five sessions. A 12th trial was designed to emulate a "morning-after drinking" or "hangover" measure. Subjects completed the 12th trial within one hour of wakening, following an evening when no alcohol or other drug had been consumed. This pseudo-hangover or "dry-run" measure was collected for purposes of comparative analysis with the actual hangover measure which was assessed following alcohol consumption.

Practice with the APTS battery prior to actual data collection ensured that the subjects were familiar with testing procedure and had attained peak performance levels. Subsequent analysis of practice data indicated that all subjects achieved asymptotic levels on all APTS subtests.

3. Data Collection. Subjects were requested to not ingest alcohol or other drugs 12 hours prior to the experimental session. Subjects were also requested to eat a light noon meal on the day of data collection and abstain from further eating until approved by the experimenter. Experimental sessions were conducted at the Evansville, Wyoming, Community Hall and Police Department Headquarters. The experimental sessions were conducted on two successive Fridays, with approximately half of the subjects participating during each session. The availability of microbased batteries for all subjects necessitated employing two separate but similar experimental sessions.

Immediately upon arriving at the data collection site, subjects received instructions in the general procedures regarding drinking and data collection, important paperwork was completed, and prealcohol ingestion testing was conducted. Paperwork included responding to the CHSQ and completion of Essex Corporation employment forms. Responses to the CHSQ were checked by the TBS for subject suitability for research participation. In particular, health status, medications, statements of nonsuitability, and weight were noted. "Warm-up" testing included the administration of one Intoximeter breath test and two administrations of the APTS. Pretreatment breath testing insured that all subjects were at BAL = 0.000 prior to ingesting alcohol. APTS warm-up testing insured that each subject was well practiced and performing at asymptotic levels as well as providing the prealcohol base rate data necessary for postalcohol comparison.

Alcohol was then consumed in a group setting with subjects completing the drinking within several minutes to slightly more than one hour. Each drink was mixed to obtain a total volume of approximately 32 oz. with the ratio of alcohol to mix established by the TBS. All drinks were prepared by mixing grain alcohol and fruit punch with ad libitum access to mix and ice permitted.

Within 20 to 40 minutes of completing alcohol consumption, breath monitoring was initiated. Typically, subjects would peak slightly above the

targeted level of BAL = 0.150. Further monitoring on the descending limb of the blood alcohol curve was then maintained. An obtained BAL = 0.150 ( $\pm$  .005) signaled the initiation of APTS data collection followed by a postbreath measure. Time from the start to the finish of data collection was also noted. In general, breath monitoring and APTS testing were completed in 30  $\pm$  5 minutes. Upon completion of the APTS battery measures at BAL = 0.150, subjects were allowed to eat dinner. In cases where BAL levels showed rapid decline on the descending limb of the blood alcohol curve, dinner was postponed in deference to data collection. Continuous monitoring of the descending limb of the blood alcohol curve was maintained for each subject to each of the remaining four data collection levels. When blood alcohol reached a prescribed data collection level  $\pm$  0.005, data collection procedures were again initiated. The procedures were applied in a manner consistent with those described above, insuring that standardized methods were employed throughout the study. The various data collection activities may be reviewed pictorially in Figure 3.

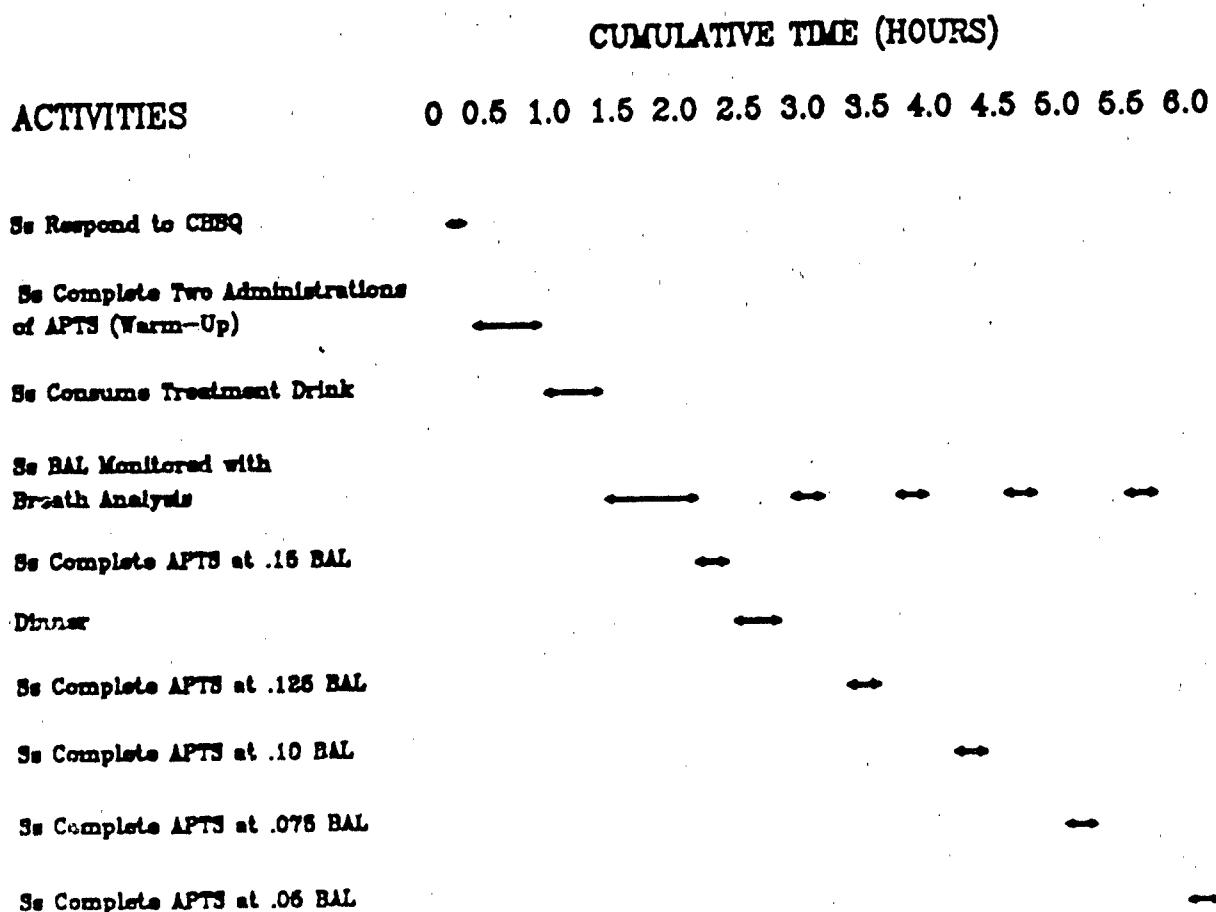


Figure 3. Approximate Timeline for Data Collection Activities

It should be noted that the recording of BAL, and corresponding time, both prior to and following data collection, provides for the interpolation of a subject's BAL at any point during the data collection process. Although not germane to the purposes of this study, data interpolation may provide insightful in future analyses. Also, during the course of the study, five subjects experienced alcohol-induced illness (i.e., vomiting). However, data losses were limited to two subjects and affected only the 0.075 and 0.050 data collection levels.

Upon completing data collection, subjects were returned to supervised housing where they were required to stay for the remainder of the evening and abstain from further consumption of alcohol.

Upon wakening the following morning, subjects self-administered one battery of the APTS. This "hangover" measure was completed within one hour of wakening and all measures were finalized by 9:30 A.M. The hangover measure typically occurred within 13 to 17 hours of the pre-alcohol APTS measure taken the previous day. Furthermore, the hangover measure closely corresponded to the practice hangover measure (obtained during practice) in terms of morning testing time and the time interval between waking and testing.

Payment for participation was remitted to subjects within three weeks of the completion of data collection, and interested subjects were thoroughly debriefed concerning their personal performance changes across BAL levels as well as the general findings of the study.

#### Results

The means and standard deviations for each of the APTS performance measures for the baseline and for each of the blood alcohol levels are shown in Table 7. The baseline was based on the average of the stable practice trials (trials 7 to 11) and on the two warm-up trials.

Average scores for each APTS subtest for each trial are shown in Figures 4 through 12. The figures depict the performance measures in the order they were obtained, beginning with the practice trials, and continuing with the practice hangover measure, the warm-up trials on the day of experimental testing, and the average scores obtained for each of the blood alcohol levels. Finally, the data point depicting the hangover measure is shown. It can be seen that, following the alcohol challenge, performance dropped dramatically on all subtests, then recovered, in most cases in a monotonic or near monotonic function, as determined by BAL during the period of alcohol metabolism. If one were to choose a single subtest to index BAL, Code Substitution would be a likely candidate. For this test it can be seen that each change of one hundredth of a percent BAL is indexed by a change of approximately 1.5 points on the Code Substitution task.

TABLE 7. DESCRIPTIVE STATISTICS FOR APTS PERFORMANCE MEASURES  
(N = 20 for .15, .125, and .10 BAL; N = 18 for .075 and .05 BAL)

APTS TEST	BLOOD ALCOHOL LEVEL											
	BASELINE		.15		.125		.10		.075		.05	
	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
GR*	22.0	7.1	17.0	6.3	20.9	6.2	23.5	7.4	23.0	8.7	23.6	8.0
MP*	66.1	13.8	62.1	16.0	64.3	15.2	68.8	11.1	74.4	11.9	73.2	12.2
CS*	43.5	10.0	34.1	8.8	37.2	11.5	41.5	11.4	44.7	9.2	48.3	10.4
PC*	64.5	10.6	55.3	12.0	57.4	15.0	63.3	11.5	64.2	10.3	67.6	12.0
MK*	55.1	14.1	48.8	12.5	49.7	17.8	59.1	12.9	61.3	13.8	61.9	12.6
STM*	38.7	4.6	35.6	4.9	36.7	5.0	36.3	5.7	39.3	5.0	40.7	4.3
RT**	0.43	0.13	0.56	0.26	0.48	0.13	0.49	0.17	0.41	0.08	0.40	0.08
NPT***	34.2	10.4	31.7	9.9	32.8	9.2	33.4	8.0	36.2	10.2	37.3	9.4
THT***	43.0	7.1	36.8	7.7	37.7	7.2	39.5	6.6	42.0	6.8	43.2	7.4

\* Number correct

\*\* Average Response Time (seconds)

\*\*\* Number of alternate key presses

NPT = Nonpreferred-Hand Tap

MP = Math Processing

PC = Pattern Comparison

STM = Short-Term Memory

THT = Two-Hand Tap

GR = Grammatical Reasoning

CS = Code Substitution

MK = Manikin

RT = Reaction Time-4 Choice

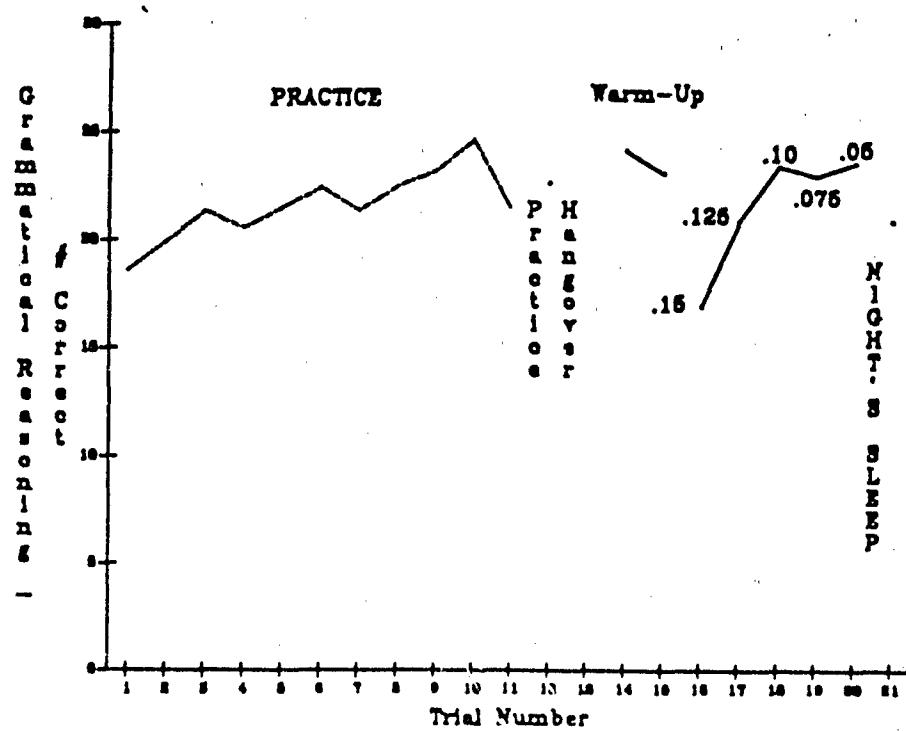


Figure 4. Experimental Results for Grammatical Reasoning Subtest

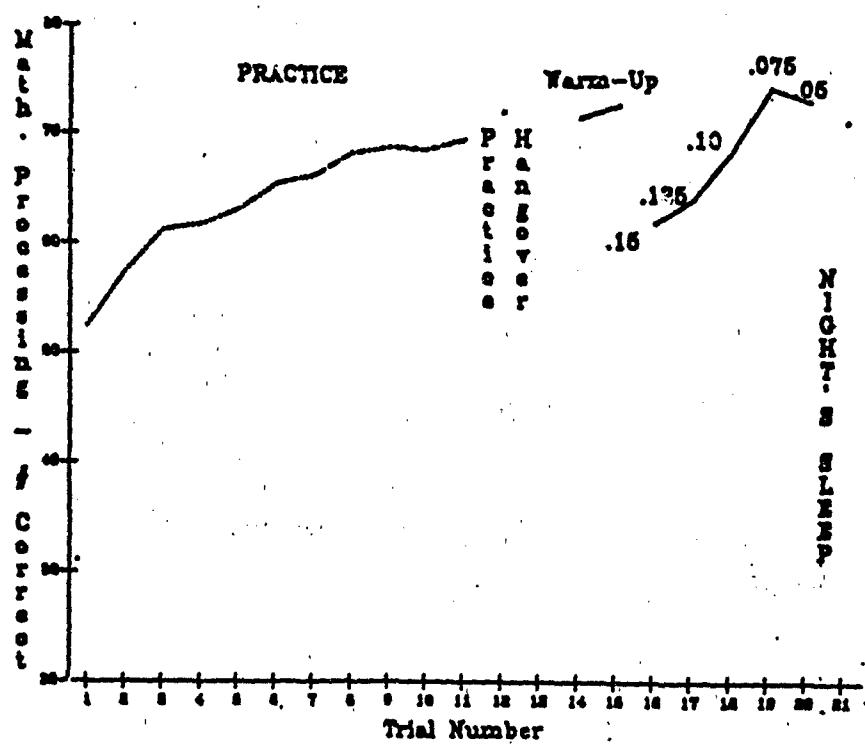


Figure 5. Experimental Results for Math Processing Subtest

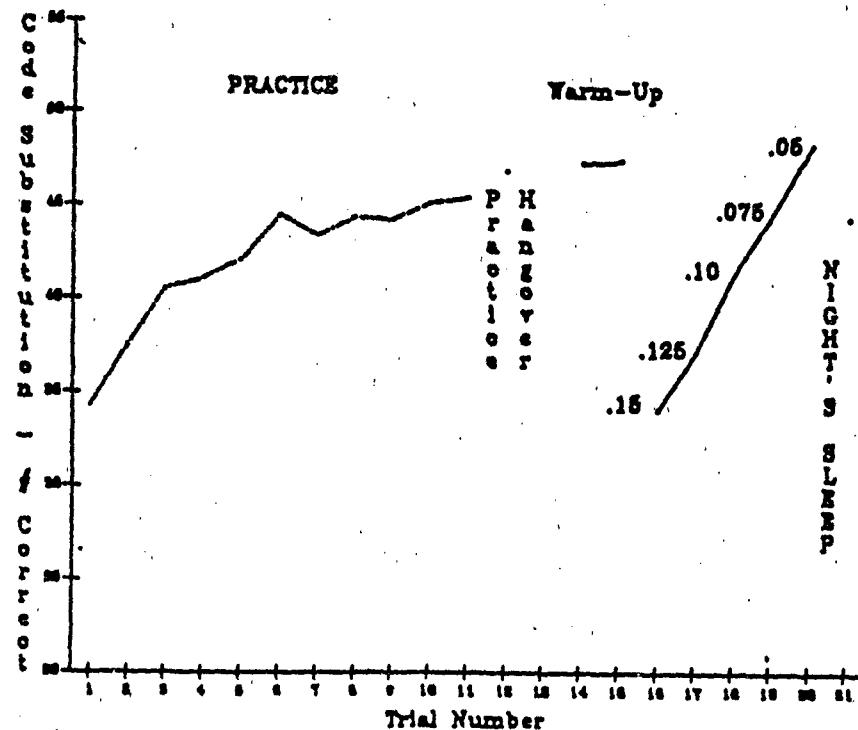


Figure 6. Experimental Results for Code Substitution Subtest

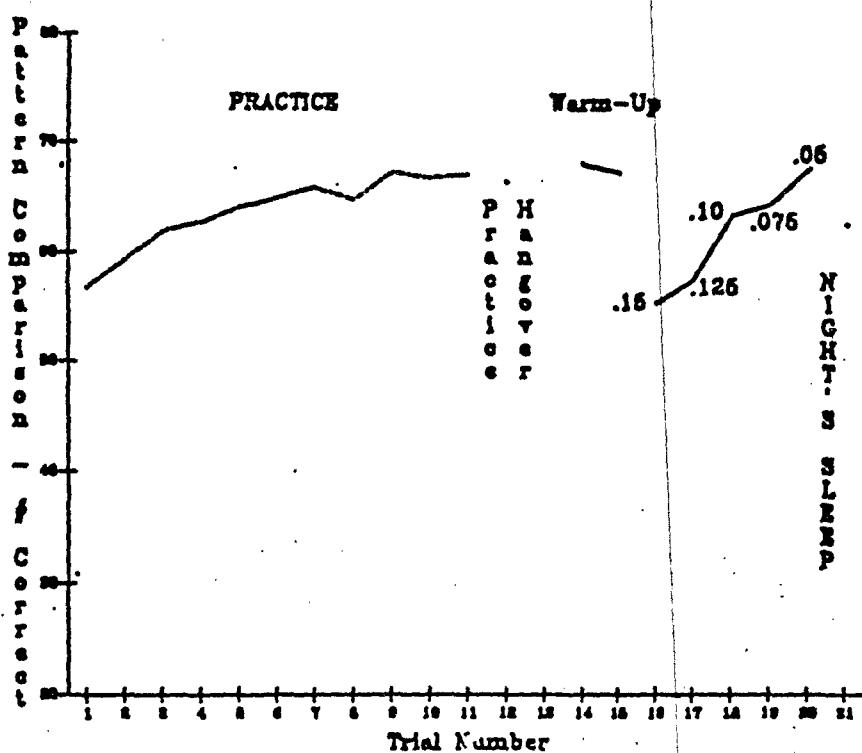


Figure 7. Experimental Results for Pattern Comparison Subtest

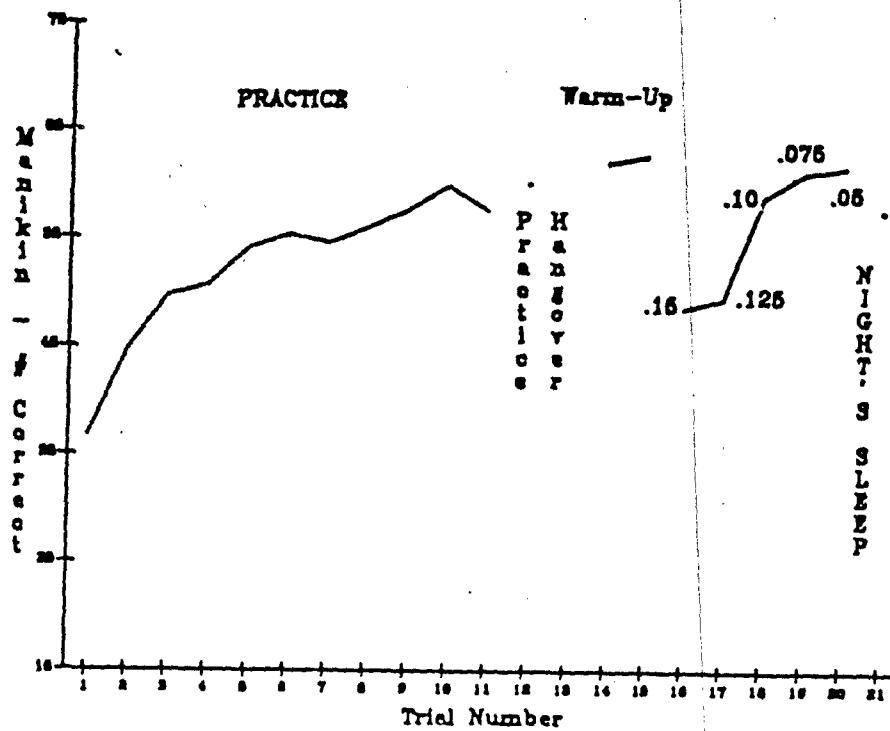


Figure 8. Experimental Results for Manikin Subtest

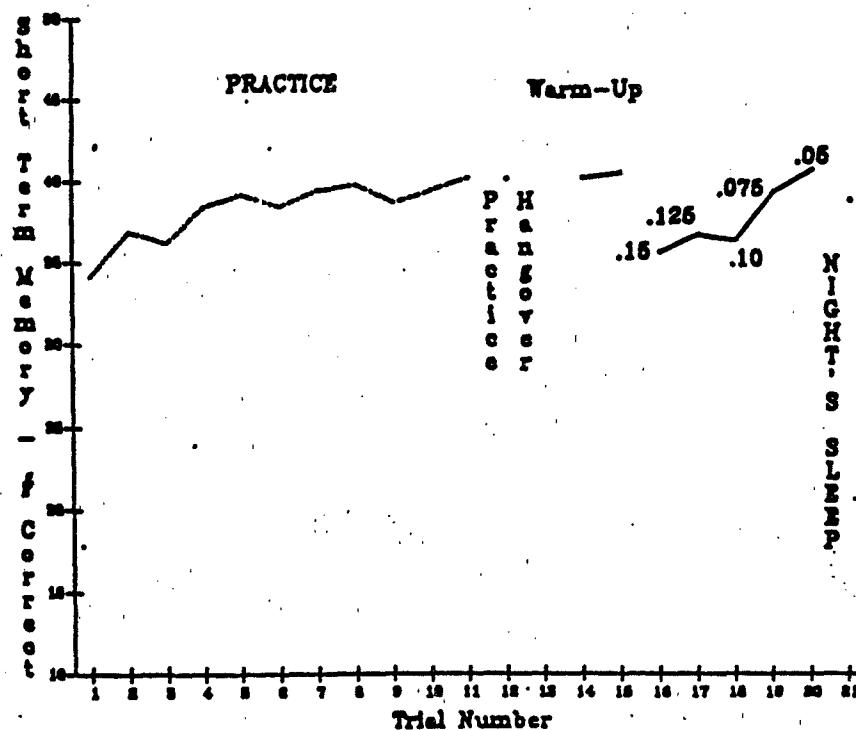


Figure 9. Experimental Results for Short Term Memory Subtest

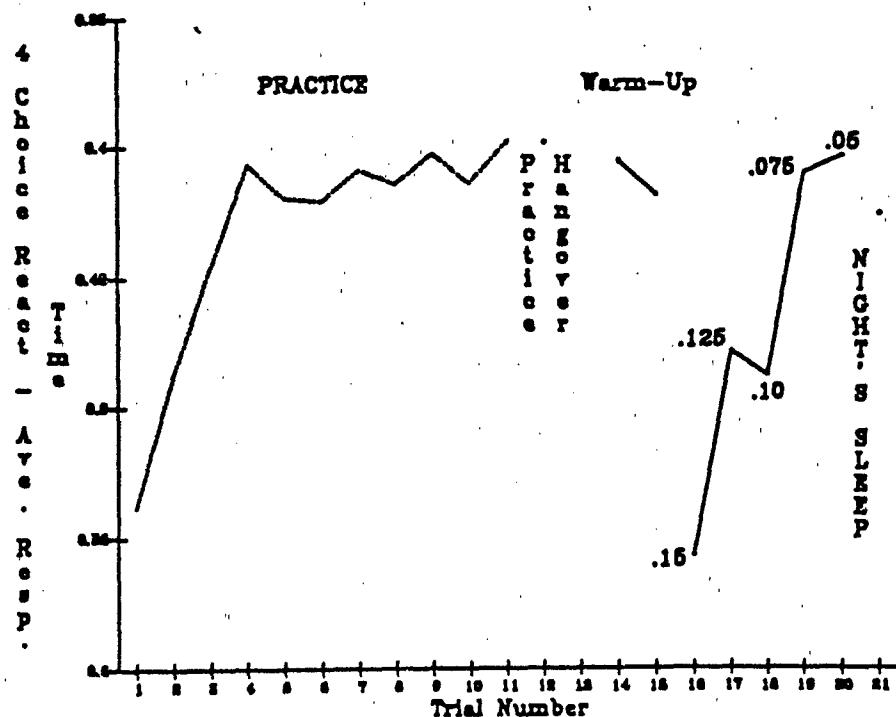


Figure 10. Experimental Results for Four Choice Reaction Time Subtest

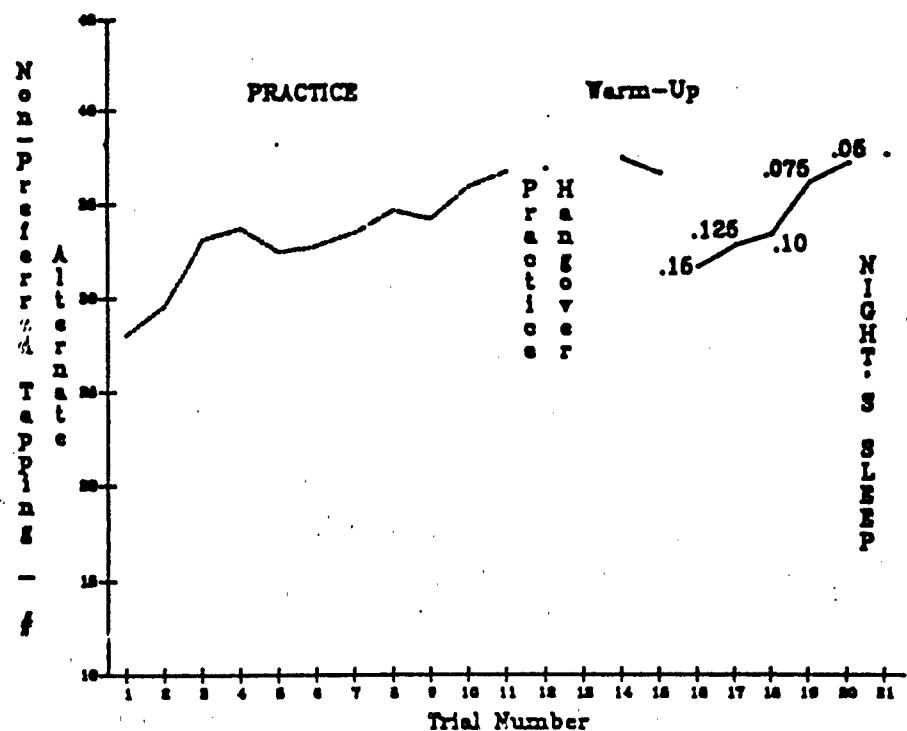


Figure 11. Experimental Results for Nonpreferred Hand Tapping Subtest

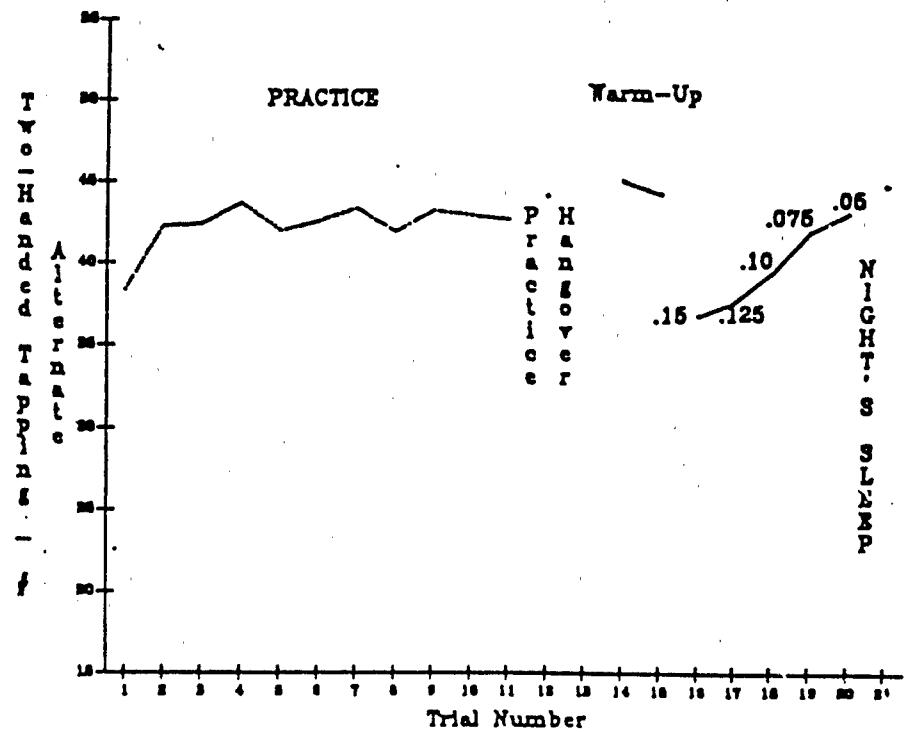


Figure 12. Experimental Results for Two Hand Tapping Subtest

### Formulation of the Quantitative Dose Equivalency Model

The fundamental concept behind the approach taken in the present research is that a carefully selected short battery of highly reliable performance tests can be used to bridge or connect two fundamental constructs, military performance readiness as represented by the connection between the surrogate performance measures and the ASVAB, and performance impairment as represented by the dose equivalence of the performance tests relative to blood alcohol concentration.

Multiple regression was used to develop a composite Surrogate Battery Percent Decrement (SBPD-1) scores that maximally predict BAL. The multiple regression between BAL as predicted from all nine surrogate battery subtests was 0.77. Subsequent stepwise regression analysis revealed that using an optimally selected subset of only four of the subtests (SBPD-2) produced a multiple R of 0.765; therefore, virtually no loss in predictive power resulted from use of the shortened battery. When this coefficient is corrected for shrinkage, R equalled 0.75; therefore, 57% of the variance in blood alcohol is predictable from the four subtest battery. The resulting regression equation (simplified by rounding to whole numbers) is shown in Equation (3):

$$\text{BAL} = 0.3 - (9\text{CS} + 2\text{GR} + 5\text{MP} + 6\text{TFT})/10000, \quad \text{Equation (3)}$$

where CS, GR, MP, and TFT, refer to percent decrement from baseline of Code Substitution, Grammatical Reasoning, Math Processing, and Two-Finger Tapping respectively. The correlation between this composite of the four subtest decrements (i.e., SBPD-2) and actual BAL was .76532.

Equation (3) is to be used as follows. Percent decrement scores (SBPD-2) from baseline of the above four tests should be computed for an actual exposure to an irritant gas (or actual exposure to whatever gases result from the operation of the target weapons system) of a known concentration for a known duration. These percent decrement scores (SBPD-2) are then entered into Equation (3) and the result is the alcohol dose equivalence score for that particular exposure.

To further demonstrate how the four test surrogate battery surfaced by the above research can serve as a bridge between alcohol (the indexing agent) and military performance readiness (the synthetic ASVAB) we computed one further regression equation from the synthetic ASVAB data described above. Equation (4) predicts the ASVAB (scaled with mean = 100 and SD = 15) from Code Substitution, Grammatical Reasoning, and Math Processing. Two Finger Tapping was not used as its beta weight in the equation was quite low. The equation is:

$$\text{ASVAB} = .92\text{CS} + .42\text{MP} + .15\text{GR} + 26 \quad \text{Equation (4)}$$

where CS, MP, and GR are raw scores for Code Substitution, Math Processing, and Grammatical Reasoning, respectively. Using this equation to fit the data from the alcohol study, we can represent the performance decrements produced by the various BAL levels relative to a metric based on a standardized ASVAB as follows. These relationships are shown in Table 8 and graphically depicted in Figure 13. The actual predicted scores for each subject under each blood alcohol condition appear in frequency histograms in Appendix G.

TABLE 8. PREDICTED STANDARDIZED ASVAB MEANS AND STANDARD DEVIATIONS FROM SURROGATE BATTERY PERFORMANCE AS A FUNCTION OF BLOOD ALCOHOL LEVEL

BAL	Mean ASVAB	SD
Baseline	103.6	12.3
0.050	104.7	13.4
0.075	101.8	12.7
0.100	96.5	13.9
0.125	90.3	15.9
0.150	85.9	13.4

In Figure 13 we have provided a normal curve to signify the previous populations' predicted ASVAB score (Kennedy, Baltzley, Lane, Wilkes & Smith, 1989). In the top panel, using the regression weights in equation (4) we have shaded in the baseline performance of the experimental population in the present study. Note that the population average here is slightly higher than the reference population, and we have normalized all scores ( $M = 100$ ;  $SD = 15$ ) so that the mean of the experimental population is seen to be at 106; - which agrees with Table 8. In each subsequent panel we have shown the alcohol effect by creating predicted ASVAB scores from APTS subtests and the figures show quite dramatically that what started out as a slightly better than average population (Category IIIA) under baseline conditions becomes a borderline Category IV/IIIB with ingestion of .15 BAL. Recovery to better scores is attendant on removal of alcohol as time ensues so that when .05 BAL is reached, the subjects are nearly back to their normal state.

As can be seen, the predicted impact of the highest alcohol dosage is greater than a full standard deviation on the synthetic ASVAB. The only dose for which there is no apparent decrement in terms of the predicted ASVAB is the 0.05% BAL.

#### DISCUSSION

Performance decrements can be expected to occur in combat due to exposure to irritant gases. These changes may be due to direct physiological stimulation or they may be due to distraction and loss of well being. In either case, it is necessary to provide a metric which can be employed to evaluate these changes. The purpose of this project was to develop a quantitative definition of soldier performance degradation due to exposure to irritant gases by two linking approaches: Surrogate Measures and Dose Equivalence. Surrogate measures are related to, or predictive of, a construct of interest but are not direct measures. The Surrogate measurement approach may be necessary because operational performances are difficult if not impossible to measure reliably.

Dose equivalence refers to an experimental method where performance deficits produced with a controlled (and relatively benign) indexing agent, in this case alcohol, are first calibrated against that agent. Then decrements in performance in the presence of irritant gases can be calibrated in terms of

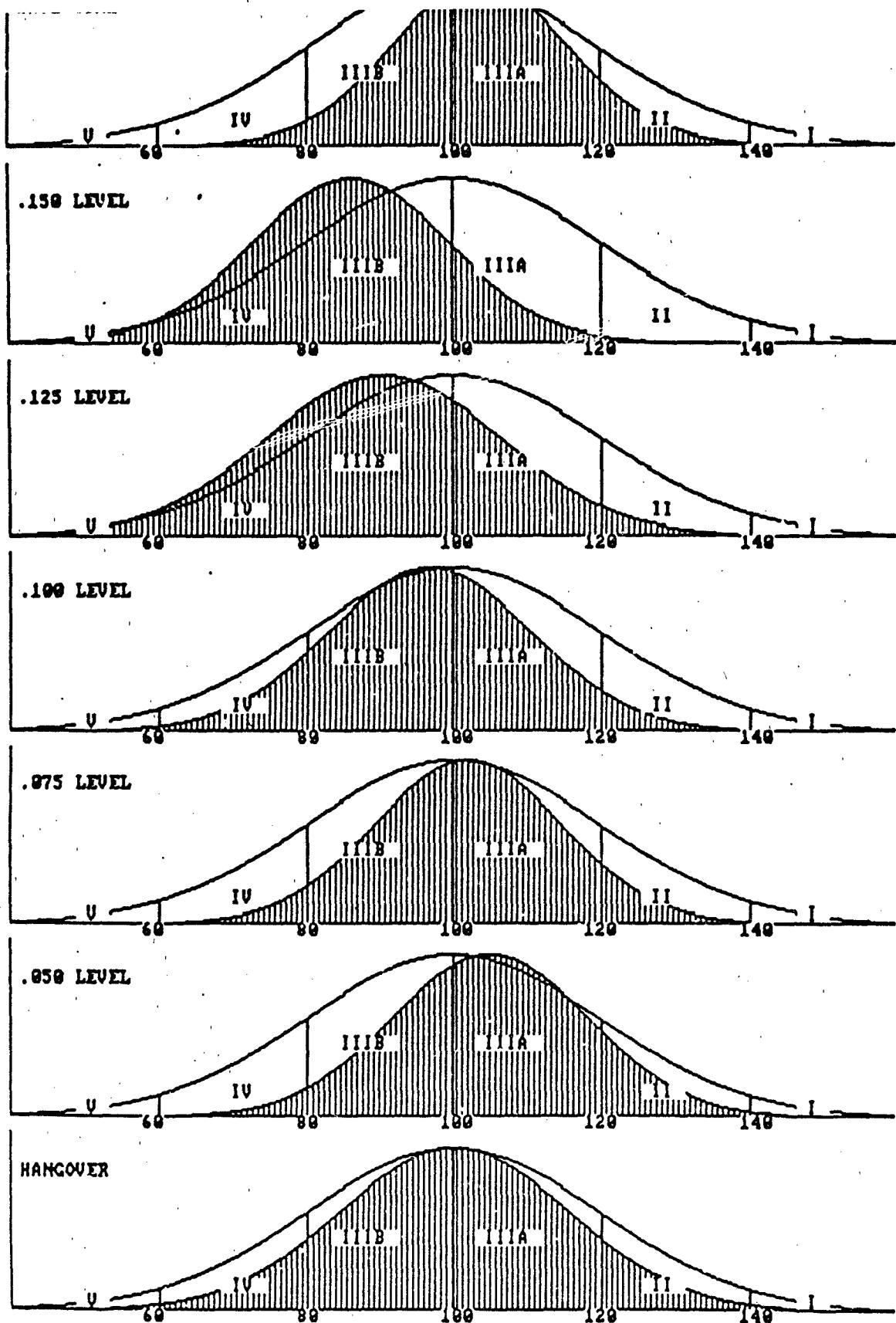


Figure 13. Effects of Alcohol on APTS Indexed to Total ASVAB Scores

their dose equivalence relative to the effects of alcohol. To quantify the human mental acuity functions which are related to military jobs, a portable microcomputer menu of tests, the Automated Performance Test System (APTS) was employed.

The first task in the Phase I research project was to describe the relation between the subtests of the APTS battery and subtests of the ASVAB, an instrument known to be predictive of military job performance. The second task was to collect and analyze alcohol data under tightly controlled experimental conditions. It was shown that the APTS battery was highly predictive of a facsimile of the ASVAB ( $R = .88$ , corrected for shrinkage). This indicates that when shrinkage owing to the particular sample used is taken into account, 77% of the ASVAB variance is explained by performance on the battery subtests. Second, it was shown that performance on the APTS bore a monotonic relationship to alcohol dosage. From these data regression equations were developed in order to provide a dose equivalency indexing metric to which other treatments could be compared (viz., blood alcohol level). When experiments are performed with irritant gases, these equations permit (1) performance deficits to be described in terms of BAL, and (2) comparison of the degradation due to the irritant gas to a change in the basic capability (i.e., vocational aptitude) of the population. Since the ASVAB is related to military performances, the inference is direct that such changes can be expected to degrade operational military performances as well.

#### ESTIMATE OF TECHNICAL FEASIBILITY

Based on the results reported herein using a facsimile of the ASVAB, we are encouraged that were: (a) an authentic full scale ASVAB administered; (b) to a larger population; (c) on two occasions (in order to obtain retest reliability); and (d) along with suitable subtests from the APTS; then various dosages of irritant gases regression equations could be created which could provide medical management and exposure guidelines based on a quantitative definition of soldier performance. These algorithms could be employed in military standards and engineering specifications for new equipments.

Moreover, whereas the full scale ASVAB is a global measure of mental acuity, the subtests themselves possess factor specificity (i.e., 3-5 factors) which might behave differently to different treatments (i.e., irritant gases). Therefore, should a particular irritant gas act on specific neural structures more than others, it may be possible to show this specificity of effect if the full subtest factor structure could be created. This was not feasible in the small sample of the study reported above. Once such a relation was available however, it may then be possible to attribute the site of action of the gas on the neural structure involved. Therefore, in future work, we would advocate that subjects which are employed (perhaps as many as 100) receive the ASVAB from a regular (run by the U. S. Army) testing station. This population would then also receive a series of APTS tests. Regression analyses would be obtained where each subtest in the ASVAB could be predicted from different combinations of APTS subtests. This reference sample may not need be exposed to the conditions of the irritant gas experiment. Their purpose would be to establish the regression weights for constructing a predicted or "as if" ASVAB total score and a predicted family of subtest factor scores. Once these regression weights were obtained, it should be possible to use these prediction equations in subsequent studies where

subjects are exposed to the experimental treatments taking APTS tests and recreating ASVAB like scores from these relations.

#### SUMMARY

The objective of the effort reported herein was to provide a quantitative methodology to permit assessment of performance degradation in humans which may result from exposure to toxic agents encountered on the battlefield. The scientific literature has shown that performance on the ASVAB is correlated with military job performance and a microcomputer test battery (APTS) has been developed which is sensitive to gases like halon and to various toxic agents. Using these relations, the present study was conducted, the results of which are clear cut:

- o Performances on APTS subtests are correlated with subtests of a synthetic ASVAB.
- o Increasing dosages of alcohol result in monotonically greater performance decrements on APTS subtests.
- o The performance decrements can be indexed to percent blood alcohol via a linear regression equation.
- o Performance decrement on APTS can be indexed to performance decrement on ASVAB via a linear regression equation.
- o Performance equivalency and dose equivalency relationships were successfully demonstrated so that:
  - a regression equation can be created which translates reductions in APTS performance due to a treatment such as a mixed gas, into ASVAB equivalent performances and
  - a regression equation can be created which translates reductions in performance due to a treatment such as an irritant gas, into units of percent blood alcohol.

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**APPENDIX A**  
**DESCRIPTIONS OF APTS' SUBTESTS**

### Tapping (two tests)

Tapping tests are motor skills/performance tasks that may be placed throughout the test battery, serving as a check against interfering factors during battery administration (e.g., boredom). Two tests were employed in the battery: Nonpreferred-Hand Tapping (NPT) and Two-Hand Tapping (THT), with the tasks respectively the first and last subtests in the battery. Both tasks require two 10-second trials with performance based on the number of alternate key presses made in the allotted time. In a recent study (Kennedy, Wilkes, Lane, & Homick, 1985), tapping was described as a psychomotor skill assessing factors common to both Aim and Spoke. Tapping has been highly recommended for inclusion in a repeated-measures microcomputer battery (Kennedy, Dunlap, Jones, Lane, & Wilkes, 1985; Wilkes, Kennedy, Dunlap, & Lane, 1986).

### Pattern Comparison (PC)

The PC task (Klein & Armitage, 1979) is accomplished by the subject examining two patterns of asterisks that are simultaneously displayed on the screen. The participant is required to determine if the patterns are the same or different and respond with a corresponding "S" or "D" key press. Patterns are randomly generated with similar and different pairs presented in random order. Pattern Comparison is presented as one 90-second trial of testing. According to Bittner, Carter, Kennedy, Harbeson, and Krause (1986), PC "assesses an integrative spatial function neuropsychologically associated with the right hemisphere." A review of PC studies (Bittner et al., 1986) indicated that the task is acceptable for use in repeated-measures research. Recent field testing with a microcomputer adaptation of the task (Kennedy, Wilkes, Lane, & Homick, 1985; Kennedy, Dunlap, Jones, Lane, & Wilkes, 1985; Wilkes et al., 1986) resulted in strong recommendations for inclusion of PC in repeated-measures microcomputer test batteries.

### Grammatical Reasoning (GR)

The GR test (Baddeley, 1968) requires the participant to read and comprehend a simple statement about the order of two letters, A and B. Five grammatical transformations on statements about the relationship between the letters or symbols are made. The five transformations are: (1) active versus passive construction, (2) true versus false statements, (3) affirmative versus negative phrasing, (4) use of the verb "precedes" versus the verb "follows," and (5) A versus B mentioned first. There are 32 possible items arranged in random order. The subject's task is to respond "true" or "false," depending on the verity of each statement with performance scored according to the number of transformations correctly identified. Grammatical Reasoning is presented as one, 90-second trial of testing. The task is described as measuring "higher mental processes" with reasoning, logic, and verbal ability, important factors in test performance (Carter, Kennedy, & Bittner, 1981). According to Bittner et al. (1986), GR "assesses an analytic cognitive neuropsychological function associated with the left hemisphere." Previous studies with GR (Bittner et al., 1986), have indicated that the task is acceptable for use in repeated-measures research. Recent field testing with a microcomputer version of the task (Kennedy, Wilkes, Lane, & Homick, 1985; Kennedy, Dunlap, Jones, Lane, & Wilkes, 1985; Wilkes et al., 1986) have resulted in strong recommendations for inclusion of GR in repeated-measures microcomputer test batteries.

### Reaction Time-1 Choice (RT1).

The Visual Reaction Time Test (Donders, 1969) involves the presentation of a visual stimulus and measurement of a response latency to the stimulus. The subject's task is to respond as quickly as possible with a key press to a simple visual stimulus. On this test the subject is required to attend and respond to only one stimulus versus multiple stimulus. A short tone precedes at a random interval to signal that a "change" in the status of the stimulus is about to occur. The participant observes the stimulus for the change and then presses the response key as quickly as possible. Simple reaction time has been described as a perceptual task responsive to environmental effects (Krause & Bittner, 1982) and has been recommended for repeated-measures research (Bittner et al., 1986; Kennedy, Dunlap, Jones, Lane, & Wilkes, 1985).

### Reaction Time-Four-Choice

The RT test (Donders, 1969) involves the presentation of a visual stimulus and measurement of a response latency to the stimulus. The subject's task is to respond as quickly as possible with a keypress to a simple visual stimulus. During this test, four boxes are displayed and a short tone signals a "change" in the status of one of the boxes. One of the boxes visually changes and the subject responds as rapidly as possible with a keypress beneath the box. Reaction Time is presented as one, 90-second trial of testing. Reaction time has been described as a perceptual task responsive to environmental effects (Krause & Bittner, 1982), and has been recommended for repeated-measures research (Bittner et al., 1986; Kennedy, Dunlap, Jones, Lane, & Wilkes, 1985).

### Associative Memory (AM)

This is a memory test (Underwood, Boruch, & Malmi, 1977) that requires the participant to view five sets of three letter trigrams that are paired with the numbers 1 to 5 and to memorize this list. After an interval, successive trigrams are displayed and the participant is required to press the key of the number corresponding to that letter set. In previous research (Krause & Kennedy, 1980) this associative memory task, using percent correct score, was recommended for inclusion in a performance test battery for environmental research.

### Manikin (MK)

The MK test (Benson & Gedye, 1963) involves the presentation of a simulated human figure in either a full-front or full-back facing position. The figure is shown to have two easily differentiated hand-held patterns. One of the two patterns is the matched pair to a pattern appearing below the figure. The subject's task is to determine which hand of the figure holds the matching pattern and respond by pressing the appropriate microprocessor key. Pattern type, hand associated with the matching pattern and front-to-back figure orientation, are randomly determined. Manikin is presented as one, 90-second trial of testing. The MK test is a perceptual measure of spatial transformation of mental images and involves spatial ability (Carter & Woldstad, 1985). Bittner et al. (1986) recommended the use of the MK test when latency scores are reported, and Kennedy, Wilkes, Lane, and Homick (1985)

identified the MK test for inclusion in microcomputer repeated-measures batteries.

#### Matrix Rotation (MR) - PAB

This test (Phillips, 1974) assesses spatial orientation and short-term memory. A series of 5x5 cell matrices that contain five illuminated cells per matrix are presented (singly). The participant compares successive displays to determine if they are the same ("S") or different ("D"). Matrices are considered alike if the same matrix is rotated either 90 degrees to the left or 90 degrees to the right from the previously displayed matrix. Two successive matrices are never presented in exactly the same orientation. The stimulus remains on the screen until the subject makes a response.

#### Code Substitution (CS)

The CS test (Ekstrom, French, Harmon, & Dermen, 1976) is a mixed associative memory and perceptual speed test with visual search, encoding, decoding, and rote recall important performance factors. The computer displays nine alpha characters across the top of the screen and beneath the corresponding digits 1 through 9. The subject's task is to associate the digits with the alpha characters and to repeat the assigned digit code when presented with alpha characters. Code Substitution is presented as one, 90-second trial of testing. Previous studies of CS (Pepper, Kennedy, Bittner, & Wiker, 1980) have indicated that the task is acceptable for use in repeated-measures research. Recent field testing with a microbased version of the task (Kennedy, Dunlap, Wilkes, & Lane, 1985) further confirmed the acceptability of this tool.

#### Mathematical Processing (MP)

The MP test (Shingledecker, 1984) includes arithmetical operations as well as value comparison of numeric stimuli. The participant performs one to three addition or subtraction operation(s) in a single presentation. Then, a response is made indicating whether the obtained total is greater or less than a prespecified value of five. The problems are randomly generated using only numbers 1 through 9. There are response deadlines for the problems corresponding to the demand characteristic of the test. Mathematical Processing is presented as one 90-second trial of testing.

#### Recall (RC) - PAB

The recall task used required the subject to view successive computer screens, each presenting two digits, one above the other. The subject's task was to indicate whether the top number on the current screen was the same as or different from the bottom number of the previous screen.

#### Short-Term Memory (STM)

The STM (Sternberg, 1966) involves the presentation of a set of four letters for one second (Positive set), followed by a series of single letters presented for two seconds (probe letters). The subject's task is to determine if the probe letters accurately represent the positive set and respond with the appropriate key pres. Subject response is recorded from the two buttons

(T=true) (F=false) on the keyboard. Performance is based on the number of probes correctly identified. Short-Term Memory is presented as one 90-second trial of testing and is described as a cognitive-type task which reflects short-term memory scanning rate (Bittner et al., 1986). Previous research with the task (Kennedy, Dunlap, Jones, Lane, & Wilkes, 1985; Wilkes et al., 1986) has indicated that STM is acceptable for use in repeated-measures research.

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**APPENDIX B**  
**PERSONAL INFORMATION QUESTIONNAIRE**

**CONFIDENTIAL**  
**PERSONAL INFORMATION QUESTIONNAIRE**  
**(PLEASE PRINT)**

**Be advised that the following information is obtained for the participants' own protection. Please answer all questions honestly.**

**I. Identifiers**

1. Name (Last, first, initial) \_\_\_\_\_
2. Social Security Number \_\_\_\_\_
3. Age \_\_\_\_\_
4. Course name, number, and hour \_\_\_\_\_
5. Dormitory \_\_\_\_\_
6. Dormitory Room Number \_\_\_\_\_
7. Dormitory Telephone Number \_\_\_\_\_
8. Home Address \_\_\_\_\_
9. City and Zip Code \_\_\_\_\_
10. Home Telephone Number \_\_\_\_\_

**II. Health Status**

1. Weight \_\_\_\_\_
2. General Health \_\_\_\_\_
3. Current Medications \_\_\_\_\_
4. Are you aware of any medical or psychological reason that should limit your participation in this study? \_\_\_\_\_ Yes \_\_\_\_\_ No

If Yes, please state why: \_\_\_\_\_  
5. Indicate your personal ability to resist alcohol induced illness (vomiting) by checking the appropriate box below:

How many 1 ounce, 80 proof drinks could you consume in 60 minutes, without becoming ill?

0	9
1	10
2	11
3	12
4	13
5	14
6	15
7	16
8	17+

**APPENDIX C**  
**CURRENT HEALTH STATE QUESTIONNAIRE**

~~CONFIDENTIAL~~

## **CURRENT HEALTH STATE QUESTIONNAIRE**

Name \_\_\_\_\_  
Social Security Number \_\_\_\_\_  
Date \_\_\_\_\_

Be advised that the following information is obtained for the participants own protection. Please answer all questions honestly.

1. Indicate your weight \_\_\_\_\_ lbs.

2. Rate your current state of health: 1 2 3 4 5

Poor	Below Average	Average	Above Average	Excellent
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3. Rate your current state of fatigue: 1 2 3 4 5

Highly Fatigued	Fatigued	Average	Fasted	Well Rested
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4. How many hours of sleep have you had in the last 24 hours? \_\_\_\_\_ Hours  
Was the amount of sleep adequate? Yes No

5. How many hours have passed since your last full meal? \_\_\_\_\_ Hours  
Have you snacked since your last meal? Yes No  
Are you currently hungry? Yes No

6. Have you taken medication in the last 24 hours? Yes No  
If Yes, indicate the type of medication, the amount taken, and when.  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

7. Have you consumed alcohol in the last 24 hours? Yes No

8. If you responded positively to Question 7, please request an alcohol breath test from the researcher.

9. Is there any reason why you should not participate in the research?

\_\_\_\_\_ Yes \_\_\_\_\_ No

If Yes, please indicate why.

**Signature:** \_\_\_\_\_

Date: \_\_\_\_\_

**CONFIDENTIAL**

**APPENDIX D**

**THE IOWA SCALE OF PREOCCUPATION WITH ALCOHOL**

**CONFIDENTIAL**

Name \_\_\_\_\_

Social Security Number \_\_\_\_\_

Date \_\_\_\_\_

**The Iowa Scale of Preoccupation with Alcohol**

**Circle the statement numbers that best apply to you.**

**I**

1. I stay intoxicated for several days at a time.
2. I worry about not being able to get a drink when I need one.
3. I sneak drinks when no one is looking.

**II**

4. Once I start drinking it is difficult for me to stop before becoming completely intoxicated.
5. I get intoxicated on work days.
6. I take a drink the first thing when I get up in the morning.

**III**

7. I awaken next day not being able to remember some of the things I had done while I was drinking.
8. I take a few quick ones before going to a party to make sure I have enough.
9. I neglect my regular meals when I am drinking.

**IV**

10. I don't nurse my drinks; I toss them down pretty fast.
11. I drink for the effect of alcohol with little attention to type of beverage or brand name.
12. Liquor has less effect on me than it used to.

**V**

Failure to respond affirmatively to the preceding items.

**APPENDIX E**

**CAHALAN VOLUME-VARIABILITY SCALE (V-V) QUESTIONNAIRE**

APPENDIX E  
CONFIDENTIAL

Name \_\_\_\_\_  
Social Security Number \_\_\_\_\_  
Date \_\_\_\_\_

CAHALAN VOLUME-VARIABILITY SCALE (V-V) QUESTIONNAIRE

1. How often do you usually have wine or a punch containing wine? (check one)

- Three or more times a day
- Two times a day
- Once a day
- Nearly every day
- Three or four times a week
- Once or twice a week
- Two or three times a month
- About once a month
- Less than once a month but at least once a year
- Less than once a year
- I have never had wine

2. How often do you usually have beer? (check one)

- Three or more times a day
- Two times a day
- Once a day
- Nearly every day
- Three or four times a week
- Once or twice a week
- Two or three times a month
- About once a month
- Less than once a month but at least once a year
- Less than once a year
- I have never had beer

3. How often do you usually have whisky or liquor, including scotch, bourbon, gin, vodka, rum, etc., or drinks containing whisky or liquor, such as, martinis, manhattans, highballs? (check one)

- Three or more times a day
- Two times a day
- Once a day
- Nearly every day
- Three or four times a week
- Once or twice a week
- Two or three times a month
- About once a month
- Less than once a month but at least once a year
- Less than once a year
- I have never had whisky or liquor

4. How often do you have any kind of drink containing alcohol, whether it is wine, beer, whisky or any other alcoholic drink? (check one).

- Three or more times a day
- Two times a day
- Once a day
- Nearly every day
- Three or four times a week
- Once or twice a week
- Two or three times a month
- About once a month
- Less than once a month but at least once a year
- Less than once a year
- I have never had wine, beer, whisky or any other alcoholic drink

**APPENDIX F**  
**INFORMED CONSENT FORM**

## INFORMED CONSENT FORM

### CHARACTERIZING SOLDIER RESPONSES TO STRESSORS

In this experiment, we are administering tests similar to the standardized tests you have taken in school from time to time, but we have transformed some of these tests onto portable, personal microcomputers so that they can be used in the field and automatically scored. Our purpose is to evaluate the tests for their sensitivity to alcohol when they are given repeatedly to the same people. The study will be of general benefit by increasing knowledge about the effects of alcohol and will help the U.S. Army improve its models of what stressors do to soldiers in battle. Our experiment will be carried out by Robert Wilkes of Essex Corporation, who may be contacted to answer questions you may have concerning the study (Phone: 307-268-2517; Address: Casper College, 125 Casper Dr., Casper, WY 82601). Should you have questions regarding the rights of human participants in research, contact Dr. H. M. Parsons, Essex IRB Chairman (Phone: 703-548-4500; Address: 333 N. Fairfax Street, Alexandria, VA 22314). Should you experience an adverse effect or hazard as a result of participation in this study, you should contact Dr. Burton Toews (Phone: 265-3791) or Robert Wilkes.

During two separate sessions, you will be required to drink alcoholic beverages over a two-hour period, raising your blood alcohol level (BAL) to either 0.0 (placebo condition, juice with rum extract floated on the top) or 0.15%. In the alcohol condition, you will drink enough alcohol to raise your BAL to, or greater than, the legal limit for driving. With respect to any risks from the study, this amount of alcohol may cause a hangover the following morning or may cause you to be nauseated, as has occurred, though rarely, in similar situations. In each session: 1) You will be required to complete a questionnaire inquiring about your current state of health, and if you elect to be considered for participation in this study, you will be required to complete a Personal Information Questionnaire and two scales measuring alcohol use. You should review these questionnaires which are attached to the Informed Consent Form. The experimenter will also review these with you. 2) Your BAL will be determined by a breath analysis administered by a technician. 3) You will be required to complete five administrations of the microcomputer test battery per session.

If you decide to participate, you will be required to allow the research directors access to your academic files for purposes of conducting research. All information so obtained shall receive confidential treatment.

Sessions\* will be held on Fridays beginning at 4:00 P.M. and ending at approximately 1:00 A.M. You will be transported to the experimental site (Evansville Police Station) and then back to a dormitory in which you are required to remain until the following morning, that being essential for your welfare and the success of the study. An experimenter will also be present in the dormitory until the following morning. You are required to eat a normal noon meal prior to each experimental session. You are further required not to ingest alcohol or other drugs for 12 hours prior to and following each experimental session (unless medication is required). Prior to the first two experimental sessions you will need to self-administer the computer tests on a daily basis for a total of six times. You will also be asked to complete the computer battery on the Saturday mornings following the alcohol testing.

As with all test batteries, there will be items which are easy and those which are difficult. No one is expected to be able to perform all the tests perfectly. You should do your best as accurately and as quickly as possible. Therefore, you should not serve as a participant any time you are not in your usual state of fitness, mentally and physically, and you will be asked to fill out questionnaires attesting to this. During the period of the experiment, if you go on medication, experience heavy pressure or stress, or do not get a good night's sleep, we ask that you alert the experimenter and reschedule your session.

All data will be encoded numerically to ensure every participant's confidentiality. Representatives of the U.S. Army Medical Research and Development Command may inspect the records of this study. Any records it inspects will not identify sources of personal data, e.g., questionnaire responses. Participation in this study is voluntary. Anyone who wishes to withdraw from participation may do so at any time. With respect to benefits to you, as a participant in this study you will become a temporary employee of Essex Corporation. A temporary employee is not entitled to any other benefits other than those required by law. You will receive \$20.00 for each session that you complete. In addition, you will receive a \$20.00 bonus if you complete all testing sessions for a total possible payment of \$60.00; Your due payment will be paid to you upon completion of the experiment or after you decide to terminate your participation. Refusal to participate will not result in any penalty or loss of benefits to which you are entitled, including loss of earned benefits or jeopardy to college grading.

Before deciding to participate in the described study there are a number of important factors you should carefully consider. Those factors may be of critical importance to you, or your safety or the validity of the research results. You must also consider the extensive time commitment required by the research in regard to your personal schedule. In particular, we ask that you not volunteer if any of the following conditions exist: (1) marginal physical or mental health state; (2) indicators of diabetes, epilepsy or other condition aggravated by alcohol; (3) necessary medications that may alter your behavior or interact with alcohol such as sedatives, hypnotics, anticonvulsants, antidepressants, tranquilizers, analgesic agents, oral hypoglycemic agents, or disulfiram; (4) inability to participate on each of the five testing sessions or during the hours required for each session; (5) past history of alcohol or drug abuse/dependency; (6) immediate family members (i.e. mother, father, sibling) with histories of alcohol or drug

\* Alcohol sessions only

abuse/dependency; and (7) inability (psychological or physical) to comply with breath sampling procedures. You will receive all necessary medical care for injury or illness that is the direct result of your participation in this research. You are advised to report to Essex Corporation, without delay, any illness or injury experienced. No financial compensation other than remuneration specifically stated in this consent form and valid medical claims directly related to illnesses or injuries suffered will be provided.

I, \_\_\_\_\_, have thoroughly read and reviewed this  
print name  
Informed Consent Form. Furthermore, I have read and reviewed the attached questionnaires. I fully understand the described research purpose, design, methods, procedures, and participation requirements. I have been provided with a copy of the consent form.

Research Participant - Signature

\_\_\_\_\_  
Date

Permanent Address: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Witness - Print Name

Witness - Signature

\_\_\_\_\_  
Date

PLEASE SIGN TWO COPIES. KEEP ONE AND RETURN THE OTHER COPY TO THE EXPERIMENTER.

Essex Corporation would like to thank you for your participation.

**APPENDIX G**

**FREQUENCY HISTOGRAMS OF PREDICTED SYNTHETIC  
ASVAB SCORES AS A FUNCTION OF BAL**

BASELINE

